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INSTRUCTION MANUAL

MODEL 48

PHASE JITTER METER

GENERAL ELECTRIC CO.
Instrumentation & Control
228 W. Florence Ave.
Inglewood, Calif. 90301

HLI

HEKIMIAN LABORATORIES, INC.

322 N. STONESTREET AVENUE

ROCKVILLE, MARYLAND 20850

INSTRUCTION MANUAL

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PHASE JITTER METER

MANUFACTURED BY

HEKIMIAN LABORATORIES

322 N. STONESTREET AVENUE

ROCKVILLE, MARYLAND 20850

PART NO. 48-100

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SECTION 1.0

INTRODUCTION

1.1 GENERAL DESCRIPTION

The Model 48 Phase Jitter Meter is designed to measure the phase modulation or "jitter", short-term amplitude variations and amplitude dropouts resulting from signal transmission through a voice frequency communications channel. High speed data transmission of 1200 bits per second and above are particularly sensitive to these parameters which rank in importance with signal-to-noise ratio, impulse noise, frequency response, and envelope delay distortion in determining channel error performance. Phase jitter and amplitude variations may be introduced by the transmission medium and terminating, multiplex, carrier and radio equipments. The ability to measure these important performance parameters and isolate those transmission links or equipments which are causing unacceptable performance is an important and necessary function in maintaining a high grade of service.

The Model 48 Phase Jitter Meter measures peak-to-peak phase jitter, phase hits, amplitude hits, amplitude dropouts, and coincident amplitude/phase hits introduced on a 990 to 1030 Hz carrier transmitted through the voice frequency channel under test. A "CAUTION" indicator warns of incorrect input frequency or level and a switchable 4 millisecond delay on the phase and amplitude hits is provided. The magnitude of the peak-to-peak phase jitter is displayed on a meter while the remaining measurements are displayed on individual mechanical totalizers.

The unit is completely self-contained and incorporates a transmit test tone oscillator for making loop measurements without additional equip-

ment. End-to-end measurements may be made using a second Model 48 or any good quality audio oscillator as a test tone source. A 60 minute timer allows unattended collection of data over preset intervals. When totalized data is not required, flashing indicator lamps may be used in place of the mechanical totalizers. An external jitter output is provided to allow chart recording or spectrum analysis, and the external carrier output may be used to accurately measure frequency offset and provide a synchronizing signal for observing phase jitter on an oscilloscope. The phase hits, amplitude hits, coincident phase/amplitude hits, and dropout indicator dc drive signals are made available through external BNC connectors for use in further defining hit and dropout characteristics. The Model 48 is self-contained in a hinged cover transit case measuring 8" wide, 14" long, and 9.5" high.

1.2 SPECIFICATIONS

The mechanical and electrical specifications for the Model 48 Phase Jitter Meter are contained in Table 1-1.

A photograph of the Model 48 is shown in Figure 1-1.

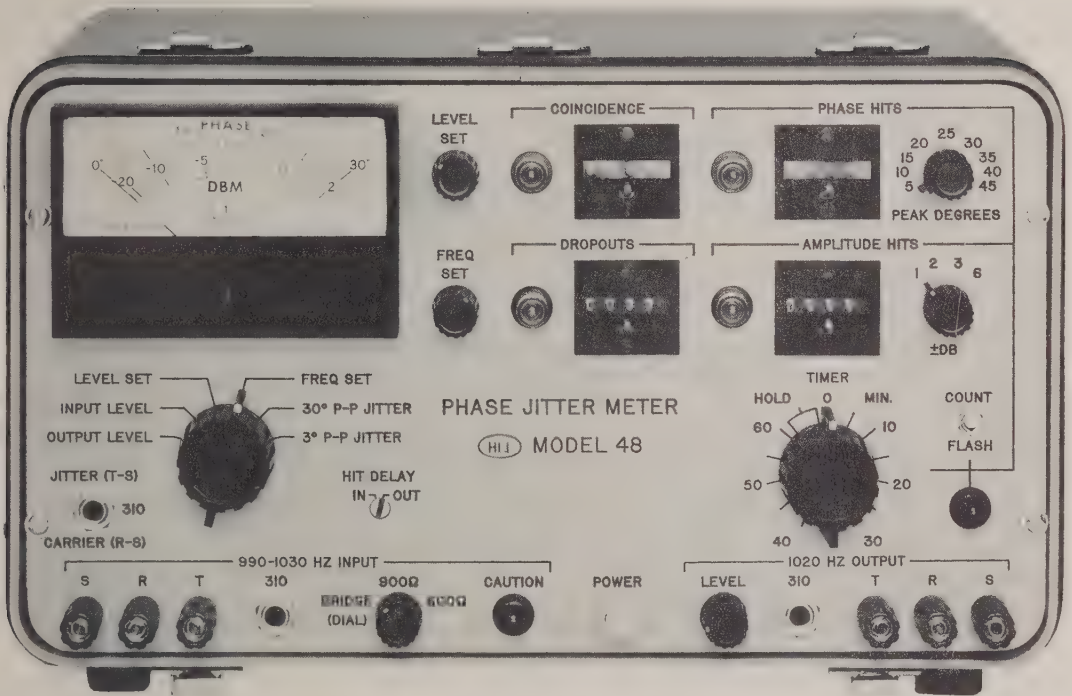


FIGURE 1–1 THE MODEL 48 PHASE JITTER METER

TABLE 1-1

SPECIFICATIONS

INPUT	
Frequency	990 - 1030 Hz
Level	-40 to +10 dBm
Impedance	600Ω, 900Ω, Bridge (10,000Ω)
Line Hold	600Ω, 900Ω, Positions
Line Hold D.C. Resistance	250Ω (maximum)
Longitudinal Balance	Greater than 40 dB 60 Hz to 40 kHz
TRANSMIT OUTPUT	
Frequency	1020 Hz ± 2 Hz
Level	-20 to +10 dBm
Impedance	600Ω
METER	
P-P Phase Jitter	3° and 30° Full Scale (± 5% plus ± 0.2°)
Input/Output Level	-20 to +2 dBm (± 1.0 dB)
PHASE HITS COUNTER	
Threshold Levels (peak)	5° steps, 5° to 45° (± 1°)
Hit Resolution	100 MS
Maximum Count Rate	7/sec
Hit Delay (IN)	4 MS
AMPLITUDE HITS COUNTER	
Threshold Levels	± 1, 2, 3, and 6 dB
Hit Resolution	143 MS
Maximum Count Rate	7/sec
Hit Delay (IN)	4 MS
DROPOUTS COUNTER	
Threshold Level	-18 dBm
Min. Dropout Duration	300 MS
Maximum Count Rate	7/sec
COINCIDENCE COUNTER	
Min. Coincidence Duration	1 MS
Maximum Count Rate	7/sec

TABLE 1-1

SPECIFICATIONS

EXTERNAL JITTER OUTPUT	
Impedance	20,000Ω
Level	100 mv/degree (approximate)
EXTERNAL CARRIER OUTPUT	
Impedance	10,000Ω
Level	8 v P-P
EXTERNAL LOGIC OUTPUTS (ALL)	
Impedance	4.7 K
Level	Inactive +28 VDC Active +1 VDC
TIMER	0 - 60 minutes
TEMPERATURE RANGE	
Operating	0° to + 50° C
Storage	-10 to +75° C
VOLTAGE	105 to 125 VAC, 50 - 60 Hz
POWER	20 watts
DIMENSIONS	8" high 14" wide 9.5" deep (with cover)
WEIGHT	16 lbs.

SECTION 2.0

INSTALLATION

2.1 GENERAL

The Model 48 Phase Jitter Meter was designed for ease of operation and installation. After the unit has been removed from its shipping container, perform a complete external visual inspection for possible damage. To inspect the interior, open the cover and detach it from the case. Then remove the two screws along the right and left hand edges of the panel and remove the inner assembly from its case. Any damage due to shipping should be immediately reported to the shipping agency.

All internal adjustments have been set at the factory and no further adjustment is required prior to installation or use of the equipment.

2.2 INSTALLATION

Primary power is supplied through the line cord packed in the compartmented cover of the transit case. The cover may be opened by counter clockwise rotation of the two fasteners holding the compartment lid. The cord is connected to the AC receptacle located through the access hole on the right hand side of the instrument.

Signal input/output lines are connected to the front panel binding posts or Western Electric 310 jacks. Shielded cabling is recommended for all input/output connections.

Connection to the JITTER/CARRIER output is made using a standard 310 tip ring sleeve phone plug. The phase hit, amplitude hit, coincident hit, and dropout outputs are available externally on BNC connectors located on the rear of the unit.

For fixed station applications, an optional rack mounting shelf is

available. This shelf mounts in a standard 19" relay rack and occupies 12 1/4 inches of verticle rack space. The behind the panel depth is 12" which includes storage provisions for the transit case cover.

SECTION 3.0

OPERATION

3.1 GENERAL

This section contains a description of the controls and indicators, operating procedures and methods of measurement to be used with the Model 48. Prior to operation be sure that all connections to the instruments are made in accordance with the instructions of Section 2.0, Installation. A photograph of the Model 48 is shown in Figure 3-1.

3.2 CONTROLS AND INDICATORS

The controls and indicators used in operating the Model 48 are described in Table 3-1. All controls are located on the front panel. No internal adjustments are required during normal operation. Adjustment procedures for internal controls are contained in Section 5.0, Maintenance.

TABLE 3-1

CONTROLS AND INDICATORS

Designation	Reference	Function
POWER Switch and Indicator Lamp	S101 DS101	Applies AC primary power to the instrument.
INPUT Terminals	J101, 102, 103, 104	Provides input connections for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
INPUT Switch	S105	Selects input line terminations of 600 ohm, 900 ohm, or bridging (10,000 ohm). Line hold provided in 600 and 900 ohm positions.
METER Switch	S102	Selects the input to the front panel meter, measures input/output level, peak-to-peak jitter, level set, and frequency set.

Designation	Reference	Function
METER	M101	Displays the parameter selected by the meter switch S102
FREQ SET Control	R104	Adjusts the frequency of the phase locked oscillator to coincide with the input frequency.
LEVEL SET Control	R126	Sets input signal to an internal reference level of 0 dBm.
CAUTION Indicator	DS105	Glows when either the input level or frequency is incorrect.
PEAK DEGREES Switch	S103	Selects the threshold degrees (peak) which must be exceeded by the phase jitter to be totalized on the phase counter.
PHASE HITS Counter	L102	Totalizes the number of phase hits exceeding the level set on S103.
PHASE HITS Indicator Lamp	DS102	Flashes when a phase hit is detected and S106 is in the FLASH position.
± DB Amplitude Hits Switch	S104	Selects the threshold in dB which amplitude fluctuations must exceed before being totalized on the amplitude hits counter.
AMPLITUDE HITS Counter	L103	Totalizes the number of amplitude hits exceeding the level set on S104.
AMPLITUDE HITS Indicator Lamp	DS103	Flashes when an amplitude hit is detected and S106 is in the FLASH position.
HIT DELAY Switch	S107	IN position rejects all phase and amplitude hits of less than 4.0 milliseconds duration.

Designation	Reference	Function
COINCIDENCE Counter	S104	Totalizes the number of coincident phase/amplitude hits which exceed their respective thresholds. Will count multiple hits from one source during an extended duration hit from the other source.
COINCIDENCE Indicator Lamp	DS104	Flashes when coincident phase/amplitude hits are detected and S106 is in the FLASH position.
DROPOUTS Counter	L105	Totalizes the number of dropouts which fall below -18 dBm for longer than 300 milliseconds.
DROPOUTS Indicator Lamp	DS106	Glows during a dropout in both the COUNT and FLASH position of S106.
TIMER	S108	Automatic timer to allow unattended accumulation of data for known time intervals. Continuous operation provided in HOLD position.
TIMER Indicator Light	DS107	Glows when the timer is in the ON position.
COUNT FLASH Switch	S106	Selects the operation of either the counters or indicator lamps.
JITTER CARRIER Jack	J109	Provides the jitter signal between the tip and sleeve (gnd) and the phase locked oscillator signal between ring and sleeve (gnd).
OUTPUT Terminals	J105, 106, 107, 108	Provides connection to the transmit oscillator, for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
OUTPUT LEVEL Control	R103	Controls the level of the transmit oscillator output.

Designation	Reference	Function
PHASE HITS Output -P	J110	BNC connection for event recording of phase hits.
AMPLITUDE HITS Output -A	J111	BNC connection for event recording of amplitude hits.
COINCIDENCE HITS Output -C	J112	BNC connection for event recording of coincidence hits.
DROPOUTS Output -D	J113	BNC connection for event recording the full duration of a dropout.

3.3 OPERATING ADJUSTMENTS

This section presents the operational adjustments used with the Model 48. These adjustments are summarized in the OPERATING INSTRUCTIONS on the storage compartment lid located in the cover of the portable case.

3.3.1 GENERAL

All adjustments and measurements are made in an idle voice frequency channel using a test signal. The test signal frequency should be between 990 Hz and 1030 Hz which accommodates both the conventional 1000 Hz and 1020 Hz "T" carrier test signals. Measurements are generally made at a test level of -13 dBm0. The test set will accept input levels from -40 to +10 dBm.

Operating adjustments are made using the actual test signal from the channel. Measurements and adjustments may be made with the test signal from a Model 48 or any good quality audio oscillator. Commercial oscillators typically have less than 1.0° peak-to-peak jitter in their output. To verify proper instrument operation, the local 1020 Hz output signal is looped to the input. Operational checkout procedures are described in Section 5.2.

3.3.2 TRANSMIT INITIAL ADJUSTMENT

To use the Model 48 as a test tone source, connect the OUTPUT terminals to the circuit under test. Using the OUTPUT LEVEL position of the meter switch, adjust the output LEVEL control for a -13 dBm0 signal. If this is below -20 dBm, an external level meter may be used in adjusting the LEVEL control, or the following procedure may be used. Loop the output to the terminated input and adjust the output LEVEL control for a level 18 dB higher than required. Adjust the LEVEL SET control for a meter

reading of 0 dBm. Now reduce the output LEVEL control until the CAUTION lamp comes on. The output is now set at the required level. As discussed in Section 3.4, test signal levels other than -13 dBm0 may be used when required.

When using a commercial oscillator be sure both the frequency and level are correct.

3.3.3 RECEIVE INITIAL ADJUSTMENT

Connect the channel under test to the 990 - 1030 HZ INPUT terminals of the Model 48, using either the five wave binding posts or the Western Electric 310 jack. Select the desired terminating impedance, and verify the proper input signal level using the INPUT LEVEL meter position. Place the meter switch in the LEVEL SET position, and adjust the LEVEL SET control for a 0 dBm reading. This sets the dropout reference level and if the input level drops 18 dB below the input signal level at the time this control is set, a dropout will be measured. Now place the meter switch in the FREQ SET position, and adjust the FREQ SET control for a center scale meter reading. The FREQ SET adjustment must be checked by varying the control and observing corresponding changes in the meter reading. An incorrect input frequency will show a steady center scale reading regardless of the control position. When the above adjustments have been properly completed, the CAUTION indicator will extinguish. If the CAUTION lamp remains illuminated, verify that the test signal frequency and level are within the operating ranges of the Model 48.

3.3.4 CAUTION LAMP

The CAUTION lamp will illuminate whenver the test signal frequency is out of range, the FREQ SET control is not properly adjusted or a dropout

condition exists. The acceptable frequency set range extends slightly beyond the bracketed center scale FREQ SET meter position. A dropout is indicated whenever the input level drops 18 dB below the input signal level at the time the LEVEL SET control is adjusted for a 0 dBm meter reading. The CAUTION lamp must be extinguished before valid measurements can be made.

3.3.5 PHASE JITTER

Following proper adjustment of the LEVEL SET and FREQ SET controls, and the extinguishing of the CAUTION light, phase jitter measurements may be made. Select the lowest peak-to-peak jitter range which gives a consistent on scale reading. When short term fluctuations of the phase jitter are present, the meter reading should be averaged to determine a final measurement figure.

3.3.6 PHASE/AMPLITUDE HITS

To measure phase and amplitude hits, the desired threshold levels should be selected on the PEAK DEGREES switch and the $\pm$ DB switch. To totalize measurements on the mechanical counters, place the FLASH COUNT switch in the COUNT position. If blinking light indications are desired, place this switch in the FLASH position. Before measured data is taken with the counters, reset them to 0 by pressing down the manual reset lever located on each counter. To initiate a measurement, turn the TIMER to the desired time interval. For intervals of less than 10 minutes the timer must be turned past the 10 minute position, and returned to the desired interval. If continuous operation is desired, turn the TIMER knob fully clockwise to the HOLD position. The timer controls the operation of both the counters and the blinking lights.

3.3.7 COINCIDENCE HITS AND DROPOUTS

The measurement of coincident hits and dropouts are made

automatically whenever the timer is on. Operation of the COINCIDENCE HIT counter or blinking light indicator is selected by the COUNT FLASH switch.

The DROPOUT indicator light will be illuminated during a dropout condition regardless of the COUNT FLASH switch position. The DROPOUT counter will operate only in the COUNT position.

A dropout condition will generally produce one phase hit, one amplitude hit, one coincident hit, and one dropout when it first occurs. When the dropout is over, no additional hits will generally be measured.

3.3.8 HIT DELAY

Phase and amplitude hits can be caused by impulse noise. To eliminate the measurement of phase and amplitude hits due to impulse noise, a 4.0 millisecond hit delay is provided which requires a hit to be present for at least 4 milliseconds before it is measured. The hit delay may be disabled (OFF) using the front panel screw driver adjusted switch.

3.3.9 FREQUENCY OFFSET MEASUREMENT

Frequency offset measurements may be made with an electronic frequency counter connected to the ring (signal) and the sleeve (gnd) connections of the CARRIER/JITTER jack. The carrier output is the phase locked oscillator which is locked in frequency and phase to the input signal. The phase locked loop provides an effective narrow band filter of approximately 20 Hz around the test signal resulting in an almost noise free CARRIER output. Extremely accurate and stable measurements may be made even in a noisy channel which would not be suitable for direct frequency offset measurements with an electronic frequency counter.

The CARRIER output may also be used to synchronize an oscilloscope used to observe the channel test signal.

3.3.10 EXTERNAL JITTER OUTPUT

The demodulated jitter signal is also available on the tip (signal) and sleeve (gnd) of the JITTER/CARRIER jack. This signal may be used for spectrum analysis of the jitter modulation to determine individual jitter frequencies and their magnitude, and may also be directly recorded on a strip chart recorder.

3.3.11 EXTERNAL COUNTER OUTPUTS

The dc voltages used to drive the counters and/or blinking lights are brought out to individual BNC connectors located on the rear of the unit. A maximum counting rate of 7 pps assures reliable operation of the electro mechanical counters and is compatible with existing Bell System standards. These outputs may be used to make chart recordings of hit and dropout occurences which provide a permanent record and may be used in performing a detailed analysis of circuit characteristics.

3.4 MEASUREMENT METHODS

This section presents a general discussion of phase jitter, and the various ways in which the Model 48 may be used to measure this important parameter.

3.4.1 GENERAL

Phase modulation of "phase jitter" introduced by voice frequency transmission facilities has an insignificant effect on voice intelligability, but can introduce errors in data transmission. Just as signal amplitude is affected by channel induced amplitude noise, i.e., thermal, crosstalk, etc., the phase of the signal is affected by channel induced phase jitter. Phase jitter generally occurs during a frequency translation process where power supply hum and power line and ringing frequency ground currents phase modulate the translation oscillators. Direct frequency modulation may also take place

under certain conditions. The resultant jitter has a nominal background level which is displayed on the meter as well as occasional abrupt changes or hits that are detected by the phase hits counter.

Phase jitter effects may also be generated by other channel parameters, principally additive wideband noise, spurious signals, (crosstalk, etc.) and amplitude impulse noise. These parameters are independently specified and measured in evaluating channel performance and their effect on the phase jitter measurement has been minimized in the design of the Model 48. Wideband noise, however, may still be a source of error in the phase jitter measurement, and will result in readings higher than the actual jitter level. Figure 3-1 shows the error which will result as a function of test signal to noise level ratios; for true phase jitter levels of 11.5° and 1° the test signal to noise ratio may be improved by increasing the test tone level up to the point of channel nonlinearity; however, this is generally not recommended.

Phase jitter in T carrier is the result of quantizing noise effects rather than the direct phase or frequency modulation of the voice frequency signal. Valid phase jitter measurements may be made directly over T carrier or tandem circuits utilizing T carrier, as these will indicate the degree of phase jitter seen by equipment connected to the circuit. However, they are not necessarily indicative of the T carrier channel quality.

Amplitude hits are short term changes in transmission loss which result from a number of causes including automatic level equalization, microwave combiner switching, etc. Amplitude hits are distinct from amplitude impulse noise; however for very high values of impulse noise test signal level changes may result which appear to be transmission loss variations.

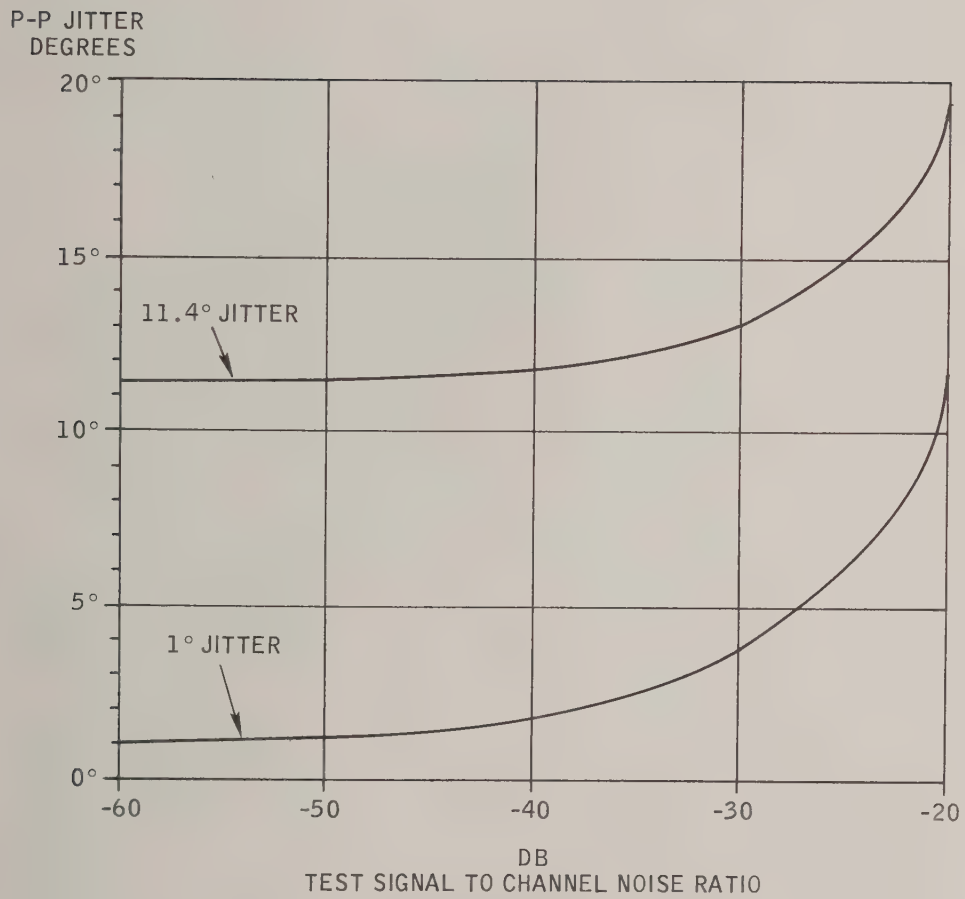


FIGURE 3–1 ERROR IN P–P JITTER READINGS RESULTING FROM VOICE FREQUENCY CHANNEL NOISE

The sensitivity of hit measurement to impulse noise is minimized by the hit delay circuitry incorporated in the Model 48.

The coincidence hits measure the number of coincident phase and amplitude hits. This is valuable in determining the source of circuit hits. Certain circuit disturbances will generate both a simultaneous phase and amplitude hits while others will generate only one type.

Dropouts are measured in accordance with Bell Specifications, and are defined as a 18 dB decrease in level for 300 milliseconds or longer. Continuous monitoring and detection of this parameter is virtually the only means of detecting its presence.

3.4.2 END TO END MEASUREMENTS

End to end measurements are made as shown in Figure 3-2. The 1020 Hz test signal may be obtained from the OUTPUT of the Model 48 or a commercial oscillator. Either balanced or unbalanced circuits may be connected to the input/output of the instrument. The transmission test level is typically -13 dBm0. The instrument is adjusted, and measurements are made in accordance with the operating adjustments of Section 3.3.

To locate sources of excessive phase jitter on a long distance point to point circuit, test signal transmissions from various voice frequency drop points may be used to isolate the segment of the circuit causing excessive jitter. The same technique may also be used in isolating local sources of jitter, by transmitting test signals from various test points within a facility or equipment.

3.4.2 LOOP MEASUREMENTS

When a far end test signal source is not available, or it is inconvenient to make end to end tests, loop measurements may be performed as shown in Figure 3-3. At the distant end, the receive and transmit

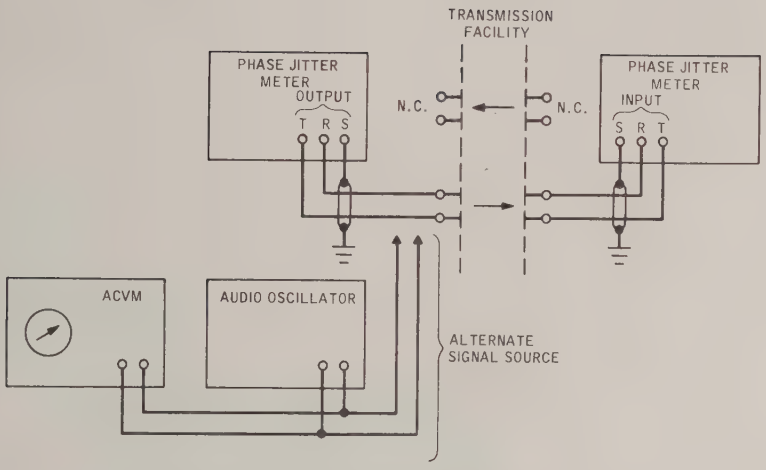


FIGURE 3–2 END TO END MEASUREMENT

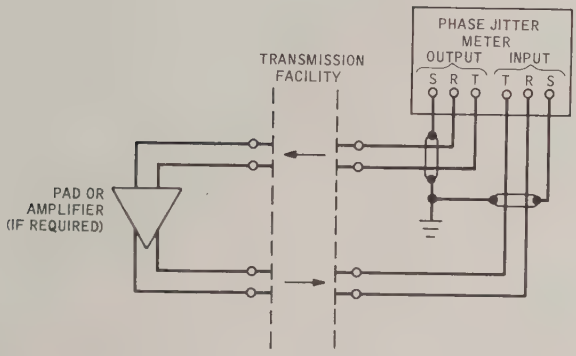


FIGURE 3–3 LOOP MEASUREMENT

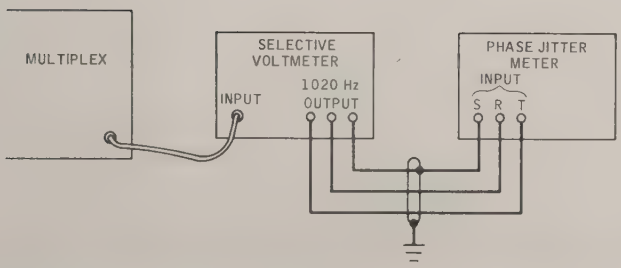


FIGURE 3–4 HIGH FREQUENCY CARRIER MEASUREMENT

levels must be matched, i.e. if the specified transmit and receive levels are not equal, it is essential that an amplifier or attenuator network be used to match them. This must be done to preserve the signal to noise ratio of the test signal and to eliminate overloading of the transmission facility.

Loop measurements are not as desirable as end to end measurements. In general, one cannot assume that the total phase jitter measured on a looped basis is equally divided between the transmit and receive circuits. In some cases, the phase jitter in each direction may tend to cancel, and unlike channel noise, will result in a lower overall loop measurement than the sum of individual end to end measurements.

3.4.3 HIGH FREQUENCY CARRIER MEASUREMENT

The Phase Jitter Meter may be used with additional equipment to measure phase jitter on carriers in a group or super group baseband. Such measurements are desirable when performing maintenance on various multiplex and carrier equipments and extend the usefulness of the instrument. To measure high frequency carriers, it is necessary to use a frequency translation device to hetrodyne the desired carrier to 990 to 1030 Hz. This is done using a tunable selective voltmeter having a translated voice frequency output.

A typical equipment connection is shown in Figure 3-4. The selective voltmeter is tuned to the desired carrier, oscillator, or pilot tone frequency, and the translated output is connected to the INPUT of the Model 48. The bandwidth of the translation device should be greater than 800 Hz but not more than 4 kHz.

When looking for low levels (less than 3°) of phase jitter using this technique, the signal to noise ratio at the output of the selective voltmeter must be taken into account in determining the true value of

phase jitter (see Figure 3-1). It is also possible that the translation device itself may introduce jitter in the translated signal.

SECTION 4.0

THEORY OF OPERATION

4.1 GENERAL

This section provides a general theory of operation followed by detailed circuit operation on a functional block basis. The Model 48 is entirely solid state and makes extensive use of integrated circuit differential operational amplifiers and conventional discrete components. Two types of differential operational amplifiers are used in the unit. Where wide bandwidth and fast rise times are required, the externally compensated type MC1437 is used, and where a 10 kHz bandwidth is adequate, the internally compensated type MC1458 is used. Discussions of operational amplifier configurations and operation are available in a number of current reference texts. Conventional transistors are used in the remainder of the circuitry. A simplified block diagram of the Model 48 is shown in Figure 4-1.

4.1.1 INPUT

The balanced or unbalanced input signal is terminated by the input switch in 600 ohm, 900 ohm, or bridging position. Line holding is provided in the 600 and 900 ohm positions by a holding coil. A two section high pass filter preceeds the input transformer, and rejects 60 cycle signals which appear at the input. The transformer is connected to the level set amplifier whose gain is manually set to provide a 0 dBm reference signal for the measurement circuitry. This amplifier is followed by a 5 pole low pass filter which attenuates spurious signals and noise above 2.0 kHz, and its output is used for the phase jitter and amplitude/dropout measurements.

4.1.2 PHASE JITTER MEASUREMENT

The filtered input signal is routed to the signal limiter which

provides a square wave replica of the input signal zero crossings, and becomes one input to the digital phase detector. This detector compares the input signal with the long time constant phase locked reference oscillator and generates DC pulses whose width are proportional to the phase difference. These pulses are then changed to a DC voltage proportional to that phase difference in the 300 Hz low pass filter. The filter output is used to control the phase locked reference oscillator, and supplies the phase jitter signal to the phase hits detector and peak-to-peak jitter detector. The phase hits detector is followed by a 4.0 millisecond hit delay designed to reduce measurement sensitivity to impulse noise by requiring that a phase hit be present a minimum of 4 milliseconds before its occurance is passed on to the phase hits driver.

The signal limiter also supplies the "out of lock" detector which is combined with the output of the dropout detector to generate the caution light indication. The caution detector output is used to inhibit all of the hit counters/lights during a caution condition and ensures that no invalid data will be accumulated.

4.1.3 AMPLITUDE/DROPOUT MEASUREMENT

The filtered input signal is also applied to the amplitude detector which consists of a full wave rectifier feeding a 300 Hz low pass filter identical to that following the digital phase detector. The filters dc output is proportional to the input level and is applied to the reference amplifier and plus and minus amplitude hit detectors. These circuits detect amplitude variations exceeding the preset threshold values, and are combined prior to the 4.0 millisecond hit delay circuitry. The hit delay output provides a signal to the amplitude hits driver and one input

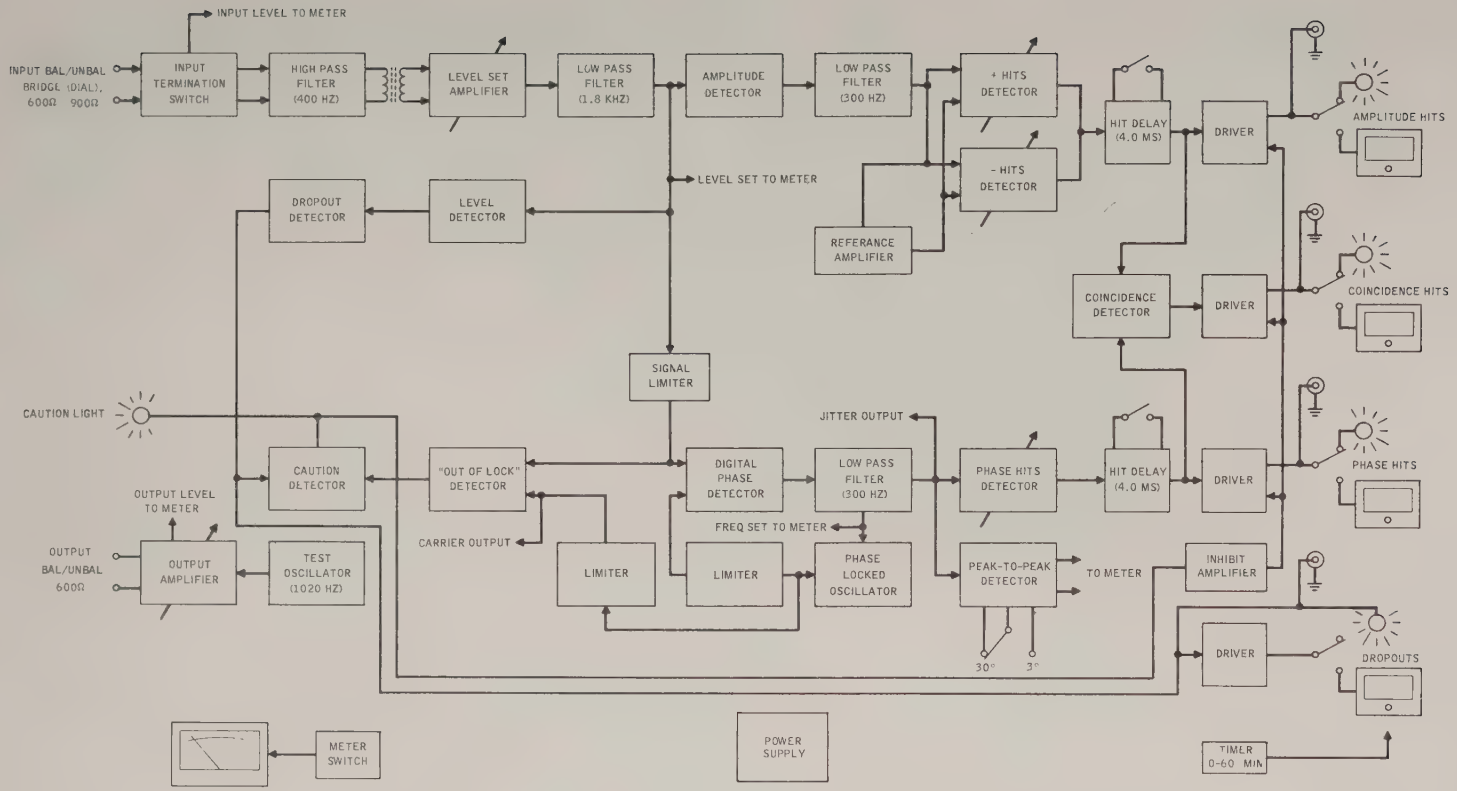


FIGURE 4–1 MODEL 48 BLOCK DIAGRAM

of the coincidence detector. This circuit detects simultaneous phase and amplitude hits and furnishes the signal to the coincident hits driver.

The filtered input signal is also used to detect dropouts. When the level detector and dropout detector measure more than an 18 dB decrease from the input signal reference level for a period exceeding 300 milliseconds a dropout condition is generated. The dropout signal is used as an input to the caution detector and the dropout driver and indicator.

4.2 DETAILED CIRCUIT OPERATION

4.2.1 LINE INPUT

The input signal is connected using a three-way binding post or a Western Electric type 310 jack. Both balanced and unbalanced signals may be accommodated. The input is terminated by the INPUT switch S105, and dc holding coil L101 is connected across the input in the 600 and 900 ohm termination positions. In the bridging position (approximately 10 K input impedance) the holding coil is removed to allow dial through operation. The signal is then applied to a 2 section high pass input filter C201, 202, R201, designed to reject 60 cycle pickup on the line. The filter output is connected to the input transformer T201 which performs the balanced to unbalanced transformation. The transformer secondary feeds a single section RC high pass filter R202, C203, followed by the input level set amplifier IC201B. Input voltage transient protection is supplied by diodes D201, 202. The gain of the level set amplifier is controlled by the front panel LEVEL SET control R126 and may be varied from -10 dB to +40 dB to provide a 0 dBm level at its output. Maximum gain is limited by R219 and C238 provides dc stabilization of the amplifier. Its output is connected to a high pass filter IC202A, IC202B, which provide a 5 pole Butterworth response using

active filter techniques, eliminating the requirement for conventional inductors. Additional 60 cycle rejection is provided by C204. The output of IC202B provides the filtered reference level input signal utilized by all of the following circuitry.

4.2.2 SIGNAL LIMITER

The input signal limiter IC301B is a differential operational amplifier used as an open loop gain zero crossing detector with dc stabilization provided by R303, 306, C339. Amplifier phase compensation is provided by C301, 303. This amplifier provides a square wave replica of the input signal zero crossings.

4.2.3 DIGITAL PHASE DETECTOR

The output from IC301B and the phase locked reference oscillator output from IC302B are connected to the 2 inputs of the digital phase detector. Transistors Q301, 302, and their associated components form an "exclusive or" gate which provides a bipolar output pulse whose width is proportional to the phase difference (zero crossings times) of the two inputs. The back-to-back zener diodes D306, 307, provide a constant amplitude pulse to the following circuitry.

4.2.4 300 HZ LOW PASS FILTER

The carrier frequency present at the output of the digital phase detector is removed, and the upper limit of the phase jitter spectrum determined by the low pass filter consisting of IC303A, B, and its related components. This filter provides a 5 pole 300 Hz Butterworth response using active filter design techniques. To achieve the desired bandwidth accuracy, 1% resistors and 5% capacitors are used in this filter. The output of the first active filter section IC303B, furnishes the signal to

the FREQ position of the panel meter through R327, and the bias offset network R328, 329. The phase locked loop control voltage is also obtained from this point. The fully filtered output is available from IC303A.

4.2.5 PHASE LOCKED REFERENCED OSCILLATOR

The output of the low pass filter is a dc voltage proportional to the instantaneous phase difference between the input and reference oscillator signals. This voltage is further filtered by the network R350, 351, and C318, 319. This network provides an over-damped phase locked loop response characteristic and its output controls a conduction angle reactance modulator consisting of emitter follower Q306, and C320, D308. This circuit effectively varies the capacitance across the Q305 oscillator tank circuit, L301 and C322, 323 and determines the output frequency and phase of the oscillator. The oscillator frequency may be adjusted using the front panel FREQ SET control R104 which varies the effective capacity of C321 across the tank circuit. The oscillator output is connected to the reference limiter IC302A which provides a square wave replica of the phase locked oscillator signal to the digital phase detector.

4.2.6 AC COUPLED AMPLIFIER

The output of the 300 Hz low pass filter is ac coupled by C314, 315, to amplifier IC304B. This amplifier provides isolation and signal amplification for the following circuitry. The external jitter output to the JITTER/CARRIER jack J109 is supplied through R336.

4.2.7 PEAK-TO-PEAK DETECTOR

The amplifier feeds the high linearity peak-to-peak detector consisting of amplifier IC304A, the positive peak detector Q307, and the negative peak detector Q308. The gain of the detector is controlled by the

meter switch providing unity amplifier gain in the 30° position, and a gain of 10 in the 3° position. R344 provides the calibration of the 30° range and R345 adjusts the calibration of the 3° range. The positive peak is stored on capacitor C316, and the negative peak on capacitor C317. Their outputs are applied to the meter through multiplier resistor R349. Compensation for input voltage offsets is provided by R340, and the adjustable divider network R341, 342, 343. This detector is calibrated in terms of the peak-to-peak value of a sine wave and responds to approximately the 97% level of white noise.

4.2.8 PHASE HITS DETECTOR

The phase hits detector consists of the full wave rectifier IC305A, B, and a variable threshold detector IC306A.

The jitter signal is applied to the full wave rectifier IC305. This circuit provides a highly stable precision full wave rectifier, independent of diode offset characteristics. Its output represents the peak value of the phase as compared to the peak-to-peak phase represented by the unrectified jitter signal. Its output is connected to a differential amplifier threshold detector IC306A which compares this peak signal to the threshold level set by the PEAK DEGREES switch S103. The output of the threshold detector remains at a positive value until the peak phase jitter signal exceeds the threshold level. When this occurs, the output abruptly changes to a negative voltage until the input signal again falls below the threshold returning the output to the positive level.

4.2.9 FOUR MILLISECOND HIT DELAY

The output of the phase hits threshold detector is connected to a 4 millisecond hit delay circuit consisting of Q309, IC306B. When a phase

hit occurs, Q309 is turned off, allowing C336 to charge towards the supply voltage. The time constants are selected so the capacitor voltage crosses the trigger amplifier threshold in 4 milliseconds, resulting in a change of state of the trigger amplifier output. This change is used to drive the phase hits counter driver circuitry and coincident detector. If the phase hit is terminated prior to the 4 millisecond interval, C336 is immediately clamped to ground by Q309 terminating its charging cycle. Phase hits of less than 4 milliseconds duration will not generate an output thus providing the desired immunity to impulse noise.

4.2.10 PHASE HITS DRIVER

The phase hits, amplitude hits, coincident hits, and the dropouts counters, and their indicator lamps use identical counter driver circuitry. A single explanation is given for the amplitude hits driver in Section 4.2.15, and this may be used with appropriate substitution of component designations for the phase hits driver circuit consisting of Q219 through Q223.

4.2.11 OUT OF LOCK DETECTOR

The out of lock detector is used to detect an out of range lock or lack of phase lock in the reference oscillator. This is then combined with the dropout detector to illuminate the CAUTION lamp if either the phase lock or input level are incorrect.

The dropout detector uses a digital phase detector Q303, 304, similar to that of the jitter phase detector. It is driven by the input signal limiter, IC301B and the out of lock limiter IC032B which utilizes a 90° phase shifted input signal, obtained through the network R357, C308. This results in a maximum positive voltage output from the digital phase detector that corresponds to the center scale meter reading in the FREQ SET meter position. As the FREQ SET control is varied in either direction, the voltage

becomes less positive, and the out of lock threshold detector IC301A is set to provide a change of output when the acceptable phase lock range has been exceeded. When phase lock has not been obtained, the output voltage has an average value of 0 volts which generates an out of lock indication from the threshold detector. The output of the digital phase detector is summed through R310, 319, with the threshold set voltage from R320. Hysteresis is provided in the threshold detector by R321, 322. When an out of lock condition exists a positive voltage appears at the output IC301A. R320 is set so that the caution lamp becomes illuminated when the FREQ SET reading slightly exceeds the acceptable range indicated on the meter face.

4.2.12 AMPLITUDE DETECTOR

The amplitude detector consists of a full wave rectifier IC201A, 203A, similar in operation to the full wave rectifier of the phase hits detector IC305. This full wave rectifier uses diodes in the feed back network to provide a half wave rectified replica of the input signal at the junction of R216, D204. This inverted signal is then summed through R218, 220, with the original signal with a ratio of 2 to 1 to provide the full wave waveform at the output of IC203A.

4.2.13 300 HZ LOW PASS FILTER

The full wave detector is followed by a 5 pole Butterworth 300 Hz low pass filter consisting of IC203B, and IC204B. The filter configuration and response is identical to the 300 Hz low pass filter of Section 4.2.4. Different circuit values are utilized to provide an overall filter gain of 6 dB.

4.2.14 REFERENCE AMPLIFIER AND HITS DETECTOR

The output of the low pass filter is connected to the reference amplifier and hit detectors. Dual threshold detectors are set to change

state whenever an increase or decrease in signal level occurs which exceeds the setting of the ± DB front panel switch S104. The outputs of these detectors are then combined to drive the amplitude hit delay circuitry.

The short term average of the filtered output is obtained by the time constant circuit R236, C237, and is applied to the input of the reference amplifier IC204A, and amplified by a factor of 2. The gain is controlled by the resistor divider network consisting of R119 through 125. The amplitude hits ± DB switch S104 selects the voltages on this divider chain corresponding to ± 1, 2, 3, or 6 dB levels which become the reference inputs to the amplitude hit threshold detectors.

The threshold detectors IC205A and B compare the output of the 300 Hz filter which contains the input signals short term amplitude variations with the average value from the reference amplifier. A small hysteresis is provided by the feedback resistors R239 through 242 and compensation is provided by capacitors C216, 217, 219, 220. When an amplitude hit occurs which exceeds the threshold setting, the output of the appropriate threshold detector will change from a positive to a negative voltage and is applied to the 4 millisecond hit delay circuit through diodes D205, 206. The operation of this circuit consisting of Q203, IC206B is identical to that described in Section 4.2.9. The output of the hit delay circuit is connected to the amplitude hits driver Q210 through Q213.

4.2.15 AMPLITUDE HITS DRIVER

The amplitude hits driver is identical to the phase coincidence and dropout drivers and the following explanation may be used for these circuits. The driver operates either the counter or the indicating lamp as controlled by the COUNT/FLASH switch S106.

The input signal is differentiated by the input capacitor C223 and the positive going edge is removed by D211. The negative going pulse is applied through R250 to the multivibrator consisting of Q210, 211. The multivibrator provides approximately a 70 millisecond "on" pulse followed by a 70 millisecond "off" pulse which is required for the mechanical counter operation. This results in a maximum count rate of 7 counts per second. The multivibrator output is amplified by Q212, which feeds the driver transistor Q213. Transient protection for the driver is provided by R257, and D212. Inhibiting transistor Q209 is included in all except the dropout detector driver, and inhibits the multivibrator operation when a positive signal is obtained from the caution detector. This eliminates the accumulation of invalid data during periods when a caution condition is present.

4.2.16 PHASE AMPLITUDE COINCIDENCE DETECTOR CIRCUITRY

Coincidence between the phase and amplitude hits is detected by diodes D209, 210. These diodes will have a negative output only when both of the inputs have dropped to a minus voltage. When this occurs, a negative impulse is fed to the coincidence hits driver consisting of Q214 through Q218. See Section 4.2.15 for a description of the driver operation.

4.2.17 DROPOUT DETECTOR

The dropout detector monitors the input signal level and is activated when the input signal drops 18 dB below the reference level for a period exceeding 300 milliseconds. The reference level is set when the LEVEL SET control is adjusted for a 0 dBm meter reading in the LEVEL SET meter position.

The dropout detector consists of the signal detector Q201, 202, and the threshold detector IC206A. Q201, 202, provide a long tail pair

peak detector circuit having excellent detector linearity, dynamic range, and dc level stability. Capacitors C212, 213, determine the dropout detector time constant, and reject dropouts having durations less than 300 milliseconds. The level detector output is connected to one input of the threshold detector IC206A where it is compared against the threshold voltage set by R2000. This may be adjusted over a range of -15 to -30 dB, and is factory set at -18 dB.

The positive output of IC206A during a dropout condition, drives the dropout driver circuitry through Q204. The dropout lamp is driven continuously through the darlington pair driver Q205, 206, so that it will remain lit during the entire dropout interval. The dropout signal is also used as one input to the caution indicator.

4.2.18 CAUTION DETECTOR

The caution detector combines the dropout and out of lock detector outputs so that the caution lamp is illuminated whenever either is unacceptable.

Diodes D219, 220, combine the positive outputs of the out of lock and dropout detectors to generate a caution condition. This positive voltage also inhibits the amplitude hits, phase hits and coincident hits multivibrators through Q209, 219, and 214 respectively. This positive voltage also drives the darlington pair Q207, 208, which controls the CAUTION lamp. Capacitor C233 provides a delay in removing the caution voltage from the multivibrator inhibit circuitry. This allows the phase locked oscillator and amplitude hits circuitry to stabilize before data is again accepted by the counters.

4.2.19 TIMER

The mechanical timer S108 controls the dc voltages to the counters and their associated indicator lamps. When the timer is on, the timer on-off lamp Ds107 is illuminated.

4.2.20 METER CIRCUIT

INPUT/OUTPUT levels, P-P PHASE JITTER, LEVEL SET, and FREQ SET, are monitored using the front panel mounted 50 microampere meter. The meter input is selected by the meter switch S102. For level monitoring, a bridge rectifier consisting of D315, 316, and R385, 386, 387, with dc isolating capacitor C337 is used to rectify the audio voltages.

4.2.21 TRANSMIT OSCILLATOR

The transmit oscillator Q310 is similar in design to the phase locked oscillator of 4.2.5. Its output is connected to the output LEVEL control R103 which is connected to the push-pull emitter coupled amplifier Q311, 312. The amplifier provides a low distortion, 1020 Hz, -20 to +10 dBm, 600 ohm test tone source for use in back-to-back and loop testing.

4.2.22 POWER SUPPLY

A commercial dual +15 and -15 volt dc power supply is utilized in this instrument. It provides a .01% line and .05% load regulation, and has a temperature coefficient of .02° per degree c. Noise and ripple on the power supply output are 1.0 millivolt rms maximum. Current capacity is 200 millamperes for each supply voltage.

The power supply is controlled by the front panel on-off push switch S101. A 1/2 amp slow -blow fuse F101 is provided for protection of the line circuitry.

The 28 volt dc power supply for the counters and indicator lamps is provided by transformer T101, and the bridge rectifiers D221 through D223. C236 is used to suppress switching transients on the 28 voltage dc bus. No filtering is required for this power supply.

SECTION 5.0

MAINTENANCE AND CALIBRATION

5.1 MAINTENANCE PHILOSOPHY

Maintenance procedures for the Model 48 are divided into preventive and corrective classifications. Preventive maintenance consists of the routine performance checks which may be made using the front panel controls of the instrument. Corrective maintenance covers the symptom analysis, trouble shooting, repair and recalibration of the instrument.

5.2 PREVENTIVE MAINTENANCE

5.2.1 GENERAL

The preventive maintenance procedures described in the following sections are used by the operator and the maintenance personnel to verify proper instrument operation using the front panel controls. If proper operation is not achieved, see Section 5.3 for corrective maintenance procedures.

Periodic cleaning, lubrication or inspection of the Model 48 is not required.

All of the following checks are made in using the 1020 HZ OUTPUT signal as an input. Connections between the OUTPUT and INPUT terminals may be made using clip leads or an appropriate test cord. The LEVEL SET and FREQ SET controls are adjusted in accordance with Section 3.3 for all of the following checks.

5.2.2 INPUT/OUTPUT LEVEL CHECK

Place the meter switch in the OUTPUT LEVEL position and verify that the output level may be adjusted over a -20 to a +2 dBm range. Set the OUTPUT LEVEL control at 0 dBm, and then monitor the input level. The input

reading should agree within ± 0.5 dB of the output level reading.

Absolute calibration of the internal level meter may be checked by comparison with an external standard meter connected in parallel across the INPUT terminals.

5.2.3 JITTER MEASUREMENT CHECK

Verify that both the 3° and 30° P-P JITTER positions of the meter switch indicate less than 0.15° and 1.5° residual readings respectively. Then swing the FREQ SET control rapidly and verify an upscale meter reading on both ranges.

5.2.4 PHASE HITS CHECK

Place the TIMER in the HOLD position, and the phase hits PEAK DEGREES switch in the 5° position. Swing the FREQ SET control rapidly and verify that phase hits are indicated.

5.2.5 AMPLITUDE HITS CHECK

Place the meter switch in the INPUT LEVEL position, and adjust the output LEVEL control for a 0 dBm reading with the input in the BRIDGE position. Readjust the LEVEL SET control if necessary. Set the amplitude hits ± DB switch to the ± 1 position, and change the INPUT switch between the BRIDGE and 900 OHM positions, and verify that amplitude hits are indicated.

5.2.6 COINCIDENCE HITS CHECK

Place the PEAK DEGREES switch in the 5° position, and the ± DB switch in the ± 1 position. Verify that when the INPUT switch is changed back and forth between BRIDGE and 900 OHMS, and the FREQ SET control is simultaneously varied, that both phase, amplitude and coincident hits are indicated. Placing the PEAK DEGREES switch at a level where phase hits are no longer detected will cause the coincidence hits indications to stop.

5.2.7 DROPOUT CHECK

Remove the input signal (both leads must be removed simultaneously) and a dropout indication should occur approximately 1/3 seconds after removal of the input signal.

5.2.8 CAUTION INDICATOR CHECK

Place the meter switch in the FREQ SET position, and verify that as the FREQ SET control is rotated the CAUTION lamp will light when the meter reading has gone slightly beyond the bracketed FREQ SET marks of the meter scale. With the FREQ SET control properly adjusted, reduce the output level control by 18 dB or more (dropout condition) and verify that the CAUTION lamp lights.

5.3 CORRECTIVE MAINTENANCE

5.3.1 TROUBLE SHOOTING

This section covers symptom analysis, circuit level trouble shooting and calibration procedures for the Model 48.

No specialized mechanical assembly or disassembly procedures are required. Accepted practices should be followed when repair is undertaken on main frame components or the printed circuit boards. Recommended trouble shooting techniques are based on signal tracing methods where a known input signal is used and the level and waveforms are verified as the signal progresses through the circuitry. Typical test equipment required to perform the trouble shooting procedures are listed in Table 5-1.

5.3.2 SYMPTOM ANALYSIS

The preventive maintenance checks of Section 5.2 are used to isolate the area in which malfunction occurs. Table 5.2 summarizes possible fault locations for each of the preventive maintenance tests.

TABLE 5-1

MAINTENANCE TEST EQUIPMENT

DESCRIPTION	TYPICAL MODEL NUMBER
Audio oscillator	HP 204C
Calibration Test Jig	See text
AC voltmeter	HP 400 EL
Oscilloscope, single channel, 1 MHz frequency response	Tektronix 323
Multitester	Simpson 260

5.3.3 CIRCUIT LEVEL TROUBLE SHOOTING

The following sections describe the general procedures to be used in locating malfunctions. Where appropriate, performance standards, voltage levels, or waveform descriptions are provided to assist in the trouble shooting procedures. When a circuit has the proper input signal but the correct output cannot be measured, the components associated with that circuit should be checked and replaced if defective.

Before detailed trouble shooting is undertaken, the $\pm$ 15 volt power supply voltages should be checked. Low supply voltages may result from a malfunctioning power supply or excessive current being drawn by a defective circuit. A defective integrated circuit may often be located by feeling the case temperature. Normally, the integrated circuits are moderately warm to the touch. However, when defective, they can become extremely warm, causing a painful sensation when touched.

5.3.3.1 1020 HZ OUTPUT CIRCUITRY

The output oscillator is checked using an oscilloscope. Under normal operations, a 12 volt peak-to-peak sine wave will be seen at terminal 300-2 and 300-Z, when the output LEVEL control R103 is fully clock wise. If

TABLE 5-2

SYMPTOM ANALYSIS

PREVENTIVE MAINTENANCE TEST	PROBABLE TROUBLE LOCATIONS
1. No response from any test	a. AC power cord b. Fuse c. Internal A.C. Wiring or power switch S101 d. Power supply
2. Input/Output level check	a. Q310, 311, 312 b. Meter switch S102, meter level rectifiers D315, 316 c. Meter M101
3. Jitter measurement check	
Unable to LEVEL SET	a. IC201B b. LEVEL SET control R126 c. T201
Unable to FREQ SET	a. Q310, 305 frequency incorrect b. Q301, 302, 305, 306; IC303B, 301B, 302B, 202 c. Meter switch S102
No P-P JITTER reading	a. IC303A, 304; Q307, 308
4. Phase hits check	a. IC305, 306; Q309, 219 thru 223 b. 28 VDC supply, T101, D221 thru 224 c. Counter L102, COUNT/FLASH switch S106 d. PEAK DEGREES switch S103
5. Amplitude hits check	a. IC201A, 202, 204, 205, 206B, Q203, Q209 thru 213 b. Counter L103, COUNT/FLASH switch S106 c. ± DB switch S104
6. Coincidence hits check	a. Q214 thru 218, D209, 210 b. Counter L104 c. COUNT FLASH switch S106
7. Dropout check	
No counter operation	a. IC206A, Q201, 202, 204, 224 thru 227
No light operation	a. Q205, 206
8. Caution indicator check	a. Q207, 208, D219, 220 b. IC301A, 302B; Q303, 304

no output is seen, check the oscillator circuit of Q310.

If the proper signal is present but no 1020 Hz output is seen, check the amplifier Q311, 312, and the transformer T301. The output frequency may be verified using an electronic frequency counter connected directly across the 1020 HZ OUTPUT terminals.

5.3.3.2 INPUT CIRCUITRY

The input circuitry is checked using a 0 dBm 1020 Hz input signal. With this input signal verify that the LEVEL SET control R126 may be adjusted to provide 0 dBm at terminal 200-E. If 0 dBm cannot be obtained, check for input signals on both sides of the input transformer T201.

Verify with an oscilloscope that the input signal with a level of approximately 0 dBm is present at the output of the first low pass filter stage IC202A pin 1, and the output of the second low pass filter stage terminal 200-D.

With the oscilloscope verify that the output signal on terminal 200-D appears on terminal 300-D. Verify that a $\pm$ 12 volt or greater square wave at the test frequency is present at the output of the signal limiter IC301B pin 12. This wave form is shown in Figure 5-1A. If this wave form is not seen, or either peak voltage is less than 10 volts, replace IC301.

The input level meter may be checked using the same input signal. The input/output level meter positions should read within $\pm$ 1.0 dB of the standard level as measured by an external reference volt meter. Calibration instructions are given in Section 5.3.4.2.

5.3.3.3 PHASE LOCKED OSCILLATOR

The phase locked oscillator incorporates the phase detector Q301, 302, the low pass filter IC303B, a reactance modulator Q306, LC oscillator Q305 and the limiter IC302A.

With no input signal, check with an oscilloscope for a 10 volt peak-to-peak or greater sine wave at pin 6 of IC302A. If no signal is seen, check Q305 and its associated components. If this signal is present, verify that a ± 12 volt or greater square wave is present at the output pin 2 of the reference limiter IC302. The wave form is shown in Figure 5-1A.

Connect a 1020 Hz test signal to the input, and adjust the instrument in accordance with Section 3.3. Verify that a ± 6 volts pulse train is present at the junction of R316, 317 and D306. When the FREQ SET control is properly adjusted, the wave form shown in Figure 5-1B should be seen. Note that this wave form has a frequency of twice the input frequency, i.e. 2080 Hz.

Place the instrument in an "out of lock" condition (FREQ SET control full clock wise, CAUTION light on) and monitor the output wave form of the first phase jitter low pass filter section IC303B, pin 7. This wave form is shown in Figure 5-1C, and will be a somewhat distorted isosceles wave varying at the difference frequency of the input test signal and the phase locked oscillator frequency.

Verify that a similar isosceles wave form is seen at the output of the second low pass filter stage IC303A, pin 1.

5.3.3.4 PEAK-TO-PEAK DETECTOR

The output of the low pass filter is AC coupled to an amplifier stage IC304B, and then to the peak-to-peak detector IC304A, Q307, Q308.

In the "out of lock" condition, an isosceles wave form similar to Figure 5-1C should be seen at the amplifier output, IC304, pin 7. It may have its peak slightly clipped and will have an amplitude of approximately ± 12 volts.

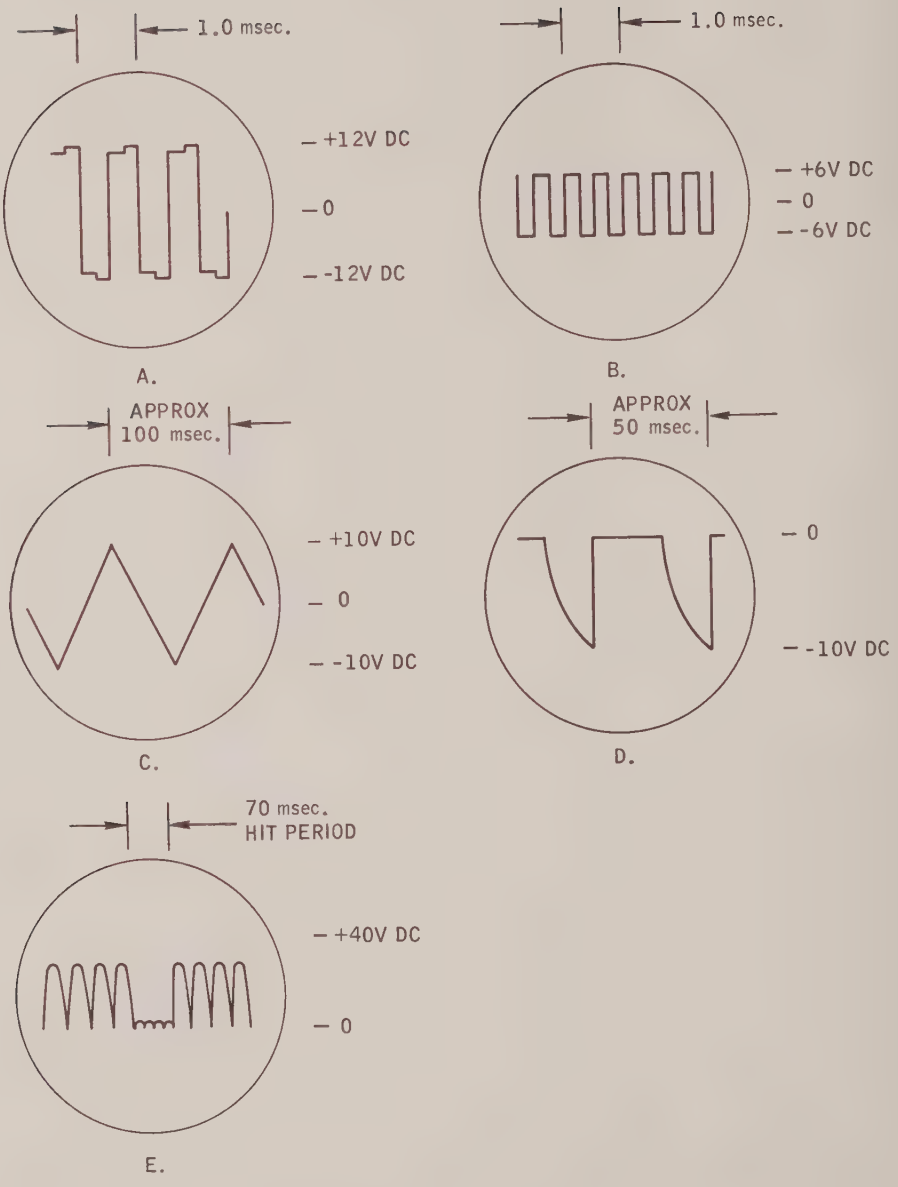


FIGURE 5–1 MODEL 48 WAVEFORMS

5.3.3.5 PHASE HITS DETECTOR

The phase hits detector takes the output of amplifer IC304B and full wave rectifies the wave form in IC305. This wave form is then fed to a threshold detector IC306 whose threshold is set by the front panel PEAK DEGREES switch. The detector output is connected to the 4 milliseconds hit delay circuit, consisting of Q309, IC306B.

In the "out of lock" condition and the phase hits switch in the 45° position, verify that a full wave rectified isosceles wave is seen at pin 1 of the IC305. It will have an approximate amplitude of 0 to +10 volts.

If the correct output is seen from the full wave rectifier, the threshold detector should have a $\pm$ 12 volt nearly square wave output. If this wave form is not seen, carefully check the phase hits switch for dirty or bad contacts, and check IC306.

With an oscilloscope, observe the wave form in the 4.0 msec hit delay circuitry at the junction of R379, C336, and D314. The HIT DELAY switch should be in the ON position. This wave form is shown in Figure 5-1D. When this wave form crosses the -7.5 volt delay threshold level, the output of the hit delay detector IC306B will change from +12 to -12 volts. Verify with an oscilloscope that this occurs.

5.3.3.6 PHASE HIT DRIVER

The multivibrator circuit values are arranged to provide an "on" time of approximately 70 milliseconds followed by an "off" time having an equal minimum duration. The procedure of Section 5.3.3.10 may be used to trouble shoot drivers.

5.3.3.7 OUT OF LOCK DETECTOR

The out of lock detector compares the limited input test signal with the limited 90° phase shifted reference oscillator signal from IC302B

in the digital phase detector Q303, 304.

The phase shifted reference oscillator output from IC302 pin 12 should resemble that shown in Figure 5-1A. In the "out of lock" condition, the voltage at pin 5 of the out of lock detector IC301A should be negative. (Use an oscilloscope to observe.) In the locked condition, the voltage should be positive. As this dc voltage goes from + to -, the output of the threshold detector IC301A pin 2, should change from +12 volts to -12 volts as measured at terminal 300-H.

5.3.3.8 AMPLITUDE DETECTOR

The amplitude detector consists of a full wave rectifier IC201A, 203A followed by a 300 Hz low pass filter IC203B, 204B. The input to the full wave rectifier is the same filtered input signal supplied to the phase jitter and dropout measurement circuitry.

With a 0 dBm meter reading in the SET LEVEL position, a -2 volt peak-to-peak full wave rectified 1020 Hz sine wave will be seen at the output of IC302A pin 1. If measured with a dc meter, the voltage will be approximately -1 volt. When the input signal is removed, the voltage at pin 1 should be 0 $\pm$ 0.1 vdc.

With approximately -1 vdc from the full wave rectifier, the output of the low pass filter Ic204B pin 7 will be -2 vdc. When the input signal is removed, this voltage should drop to 0 $\pm$ 0.1 vdc.

5.3.3.9 AMPLITUDE HITS DETECTOR

The amplitude hits detector consists of the reference amplifier IC204A, and the $\pm$ hits detector IC205.

The -2 vdc output from the 300 Hz low pass filter is supplied to the reference amplifier through the integrating network R236, C220. This amplifier has a gain of 2 which results in an output voltage at pin 1

(terminal 200-0) of -4 vdc. If this voltage is not measured, it is likely that the ± DB switch or some of its associated resistors are defective. Verify that when the input signal is removed, the output voltage drops to 0 ± 0.1 vdc. In the ± 6 dB position of the amplitude hits switch the voltages at terminals 200 K, L, will be -4 vdc and -1 vdc respectively. When no level changes are present, the outputs of the hit detectors IC205 pins 12 and 2 will be -12 vdc. When amplitude hits are generated in accordance with paragraph 5.2, the hit detector outputs will become +12 vdc during the hit detection. This may be verified with an oscilloscope. Verify that these amplitude his also appear at the junction of D205, 206.

The hit delay circuit Q203, IC206B may be checked in accordance with Section 5.3.3.5.

5.3.3.10 AMPLITUDE HITS DRIVER

The multivibrator provides an "on" time of approximately 70 milliseconds followed by an "off" time having equal minimum duration. The following trouble shooting procedure may be used to trouble shoot all of the driver circuits.

The negative going hit signal is differentiated by C223 to provide a 15 or greater volt trigger pulse across D211. This pulse triggers the multivibrator and results in a positive output pulse applied to the base of Q212. This results in a 0.7 volt pulse at the base of Q213 which drives the appropriate indicator.

Multivibrator operation is clamped when a positive voltage is applied to the inhibit transistor Q209. During these periods, no signals will be seen at the base of Q211. The typical wave form across a driver output terminal during a hit is shown in Figure 5-1E.

5.3.3.11 COINCIDENCE DETECTOR

Coincidence between the phase and amplitude hits is detected by the diode "and" gate D209-210. When a negative hit signal is present at both diode inputs, a negative signal is applied to the coincidence hits driver circuitry. The operation of this driver circuitry is identical to that described in Section 5.3.3.10.

5.3.3.12 DROPOUT DETECTOR

The dropout detector consists of the level detector Q201, 202, and the dropout threshold detector IC206A.

A normal level input signal will result in a dc voltage of +1.3 volts at the Q202 emitter output of the level detector. This voltage will drop to near 0 volts when the input signal is removed. When this voltage drops below the reference voltage set by the dropout detector calibrate control R2000, the dropout threshold detector out from IC206A pin 2 will change from -12 to +12 volts. This change is used to drive the dropouts driver circuitry through Q204, and results in a driving signal which changes from 0 to -15 volts during a dropout condition. The dropout threshold detector output is also applied to the darlington pair transistors Q205, 206 which drive the dropout indicator lamp.

5.3.3.13 CAUTION DETECTOR

The caution detector consists of a diode "or" gate followed by driver circuitry for the caution lamp. It also supplies the positive inhibit voltage to the inhibit transistors located in the amplitude, phase and coincident hit driver circuits.

Detection of an out of lock or dropout condition results in a positive output from the appropriate detectors. These outputs are combined

by diodes D219, D220, and result in a positive signal applied to the darlington pair transistors Q207, Q208, which drive the caution lamp. The same +12 volt signal is applied to the inhibit transistors Q209, 214, 219, in the multivibrators.

5.3.4 CALIBRATION

The following procedures are used to recalibrate the test tone output frequency, the input/output level monitor meter, the phase locked oscillator, the peak-to-peak phase jitter ranges, the phase hits detector, the dropout detector and the out of lock detector. Recalibration is normally required when maintenance has been performed on the associated circuitry or when there is a reason to suspect the calibration is no longer accurate.

5.3.4.1 TEST TONE OUTPUT FREQUENCY

Step A. Connect an electronic counter capable of measuring 1020 Hz to the OUTPUT terminals. Adjust the output LEVEL control until the counter is operating consistently. Adjust L302 (printed circuit board mounted inductor) to give an output frequency of 1020 Hz $\pm$ 1 Hz. L302 is adjusted using a small screwdriver to turn the adjustor slug reached through the hole in the center of the core assembly.

5.3.4.2 INPUT/OUTPUT LEVEL METER

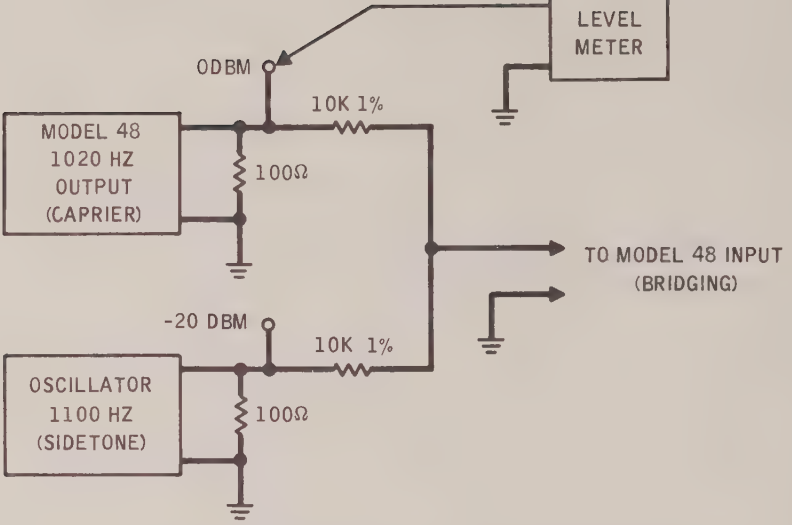
Step A. Connect the test tone OUTPUT terminals to the INPUT terminals.

Step B. Connect a standard reference meter in parallel with the INPUT terminals. Be sure all ground connections are properly made.

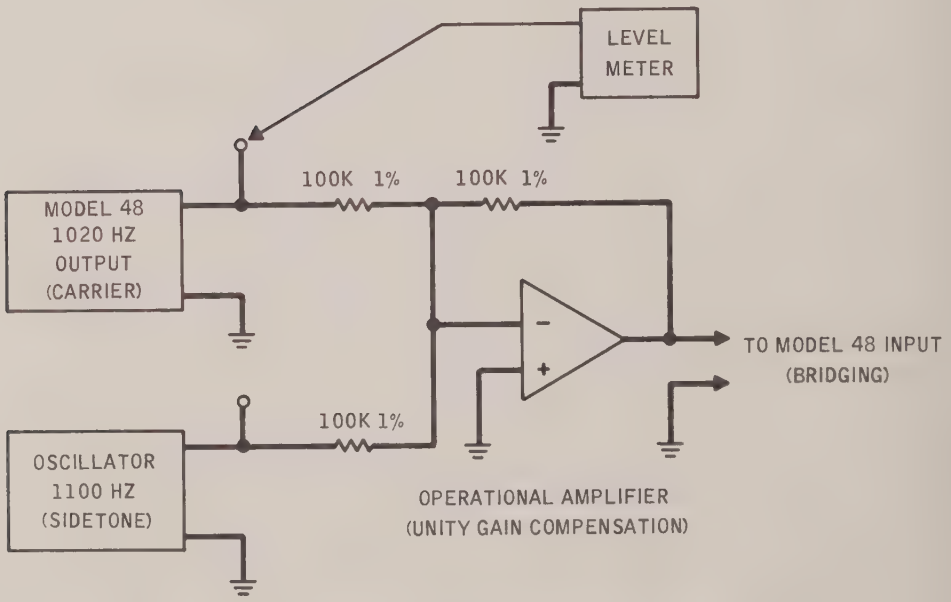
Step D. Adjust R387 to give a meter reading within 0.25 dB of the reference meter.

5.3.4.3 PHASE LOCKED OSCILLATOR FREQUENCY

Step A. Connect a 0 dBm test signal at a frequency of 1035 Hz



A. RESISTOR TEST JIG (11.5 P–P JITTER ONLY)



B. OPERATIONAL AMPLIFIER TEST JIG

FIGURE 5–2 PHASE JITTER CALIBRATION TEST JIGS

to the INPUT terminals.

Step B. Adjust the LEVEL SET control for a 0 dBm meter reading in the LEVEL SET meter position.

Step C. Place the FREQ SET control at its full counter clockwise position.

Step D. Adjust L301 (printed circuit board mounted inductor) to give a meter reading at the FREQ SET mark. L301 is adjusted using a small screwdriver to turn the adjustor slug reached through the hole in the center of the core assembly.

5.3.4.4 PEAK-TO-PEAK JITTER

Step A. The peak-to-peak jitter ranges are calibrated using a two-tone audio technique where the phase jitter is proportional to the level difference between the two tones.

Step B. To perform this calibration, two audio oscillators having 1% or less harmonic distortion are connected using the special test fixtures shown in Figure 5-2. A wide variety of integrated circuits or discrete operational amplifiers may be used in the text fixture, including the MC1437L, and MC1458G's used in the Model 48. Precision resistors of 1% tolerance are required in these networks. When external amplifier compensation is required, it should be provided for unity gain operation.

Step C. Connect the oscillators as shown to the test fixture, and then connect the test fixture to the input of the Model 48. Set the carrier oscillator for a frequency of 1020 Hz ($\pm$ 1 cycle) and set its output level to 0 dBm ($\pm$ 0.1 dB).

Step D. Adjust the frequency of the sidetone oscillator to 1100 Hz. The output level of this oscillator will be varied to obtain the desired phase jitter calibration levels.

5.3.4.4.1 30° PEAK-TO-PEAK JITTER RANGE

Step A. Temporarily disconnect the sidetone oscillator from the test fixture.

Step B. Adjust the LEVEL SET control for a 0 dBm reading in the LEVEL SET meter position.

Step C. Temporarily place the meter switch in the 3° P-P JITTER position.

Step D. Allow time for the meter to settle to its minimum reading and adjust R343 for a minimum meter reading. This adjustment should be made very slowly as the meter time constants require approximately a 5 second interval between adjustment and a meter reading. This should result in a residual meter reading of less than 0.1° peak-to-peak.

Step E. Reconnect the sidetone oscillator to the test fixture and set the meter switch to the 30° P-P JITTER range.

Step F. Adjust the sidetone oscillator for an output level of -20 $\pm$ 0.1 dBm. This setting corresponds to a peak-to-peak jitter level of 11.5°.

Step G. Adjust R344 to give a reading of 11.5°.

5.3.4.4.2 3° PEAK-TO-PEAK JITTER RANGE

Step A. Set the meter switch in the 3° P-P Jitter range. Adjust the sidetone oscillator for a level of -41.8 $\pm$ 0.1 dB. This corresponds to a peak-to-peak jitter value of 1.0°. Adjust the 3° calibration control R345 for this meter reading.

NOTE

Caution must be used in calibrating these low values of phase jitter to ensure that no noise pick up, hum, etc. is introduced by the test fixture. The carrier

oscillator must have a low level of phase jitter in its output. This can be verified by the residual meter reading obtained in Step D of 5.3.4.4.1. If this reading is not below 0.1° peak-to-peak, it should be replaced with an audio oscillator providing this residual reading. If this cannot be obtained, the output oscillator of the Model 48 may be used as the carrier oscillator.

5.3.4.5 PHASE HITS DETECTOR

Step A. Calibration of the phase hits detector is made in a similar manner to that of the phase jitter calibration. The test fixtures of Figure 5-2 may be used.

Step B. Repeat Steps A through D of Section 5.3.4.4.

Step C. Place the PEAK DEGREE switch in the 15° position and place the timer in the HOLD position.

Step D. Adjust the sidetone oscillator for a level 11.74 $\pm$ 0.1 dB below the carrier oscillator.

Step E. Place the HIT DELAY switch in the OUT position, and the FLASH COUNT switch in the COUNT position.

Step F. Adjust R383 so the phase hits totalizer just begins to count in a steady manner. Verify that counter operation can be halted by a slight adjustment of R383, and then reset to the steady counting position.

TABLE 5-3

PHASE JITTER CALIBRATION CHART

Sidetone Level	Peak-To-Peak Jitter	Application
-11.7 DB	30°	Phase hit calibration point (15° Peak Degrees)
-20.0 DB	11.4°	30° P-P JITTER range calibration point

TABLE 5-3

PHASE JITTER CALIBRATION CHART

Sidetone Level	Peak-To-Peak Jitter	Application
-41.8 DB	1.0°	3° P-P JITTER range calibration point

NOTE

Carrier oscillator set at 0.0 dBm.

5.3.4.6 DROPOUT THRESHOLD

Step A. Adjust the instrument in accordance with paragraph 5.2.2.

Step B. Without readjusting the LEVEL SET control, lower the input level 18.0 dB. An external level meter should be used to obtain accurate readings of the output level.

Step C. Adjust the dropout calibrate control R2000 to just extinguish the CAUTION light. The caution light should again illuminate when the input level is dropped an additional 0.5 dB.

5.3.4.7 OUT OF LOCK DETECTOR

Step A. Adjust the instrument in accordance with Section 5.2.1.

Step B. Set the FREQ SET control to give an equivalent meter reading of 8° in the FREQ SET meter switch position.

Step C. Adjust R320 to just illuminate the CAUTION light.

Step C. Rotate the FREQ SET control to move the meter reading to the other side of center scale. The CAUTION light should be off as the meter goes thru the bracketed FREQ SET range and should again come on at an equivalent meter reading of 20° to 25°.

TABLE 5-4 MODEL 48 MAINFRAME PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	DS101	Pilot lamp neon A 1 H.		Chicago Lamp
	DS102 thru DS107	Pilot lamp incandescent 28v, .040 amp	327	Chicago Lamp
	J101 thru J103	Binding post	29-1	Grayhill
	J104	Phonejack, 3 circuit	#12B	Switchcraft
	J105 thru J107	Binding post	29-1	Grayhill
	J108, 109	Same as J104		
	J110 thru J113	BNC connector	UG 1094/u	Amphenol
	J114	AC receptacle	160-5	Amphenol
	L101	Holding coil	C1709	Stancor
	L102 thru L105	Counter, 24 vdc, 4 digit	TCeZ4E	Sodeco
	M101	Meter, 0-50 microamp	44-001	HLI
	PS101	Power supply	2.15.200	Semiconductor Products

TABLE 5-4

MODEL 48 MAINFRAME PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R101	Resistor: fixed, composition, 620 ohm, ± 5%, 2W		Ohmite
	R102	Resistor: fixed, composition, 910 ohm, ± 5%, 2W		Ohmite
	R103	Resistor: variable, 10K	WA2605-65103UA	Allen Bradley
	R104	Resistor: variable, 10K	JAIN200P 103UA	Allen Bradley
	R105 thru R113	Resistor: fixed, deposited, 150 ohm, ± 1%, 1/4W	RN60D	IRC
	R114	Resistor: fixed, composition, 27K, ± 5%, 1/4W		Ohmite
	R115 thru R118	Resistor: fixed, composition, 4.7K, ± 5%, 1/4W		Ohmite
	R119	Resistor: fixed, deposited, 412 ohm, ± 1%, 1/4W	RN60D	IRC
	R120	Resistor: fixed, deposited, 464 ohm, ± 1%, 1/4W	RN60D	IRC
	R121	Resistor: fixed, deposited, 1740 ohm, ± 1%, 1/4W	RN60D	IRC
	R122	Resistor: fixed, deposited, 294 ohm, ± 1% 1/4W	RN60D	IRC
	R123	Resistor: fixed, deposited, 261 ohm, ± 1%, 1/4W	RN60D	IRC
	R124	Resistor: fixed, deposited, 619 ohm, ± 1%, 1/4W	RN60D	IRC
	R125	Resistor: fixed, deposited, 1500 ohm, ± 1%, 1/4W	RN60D	IRC
	R126	Same as R104		

TABLE 5-4

MODEL 48 MAINFRAME PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	S101	Switch, push, 1 pole, 2 position	616	Marco Oak
	S102	Switch, rotary, 5 pole, 6 position	V52065	JTB
	S103	Switch, rotary, 1 pole, 9 position	V520915	JTB
	S104	Switch, rotary, 2 pole, 4 position	V540415	JTB
	S105	Switch, rotary, 2 pole, 3 position	13FM3	RCL
	S106	Switch, toggle, 4 pole, 2 position	JMT-423	RCL
	S107	Switch, rotary, 2 pole, 2 position	13FM2	RCL
	S108	Switch, timer, 60 min. with hold	90024	M.H. Rhodes
	T101	Transformer	P-8395	Stancor
	TR101,102	Communications Gaps	CG-230L	Signalite

TABLE 5-5

HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	C201	Capacitor, Type MWR, .075 mfd, 5%, 200 vdc		Standard
	C202	Capacitor, Type MWR, .018 mfd, 5%, 200 vdc		Standard
	C203	Capacitor, Type MWR, .01 mfd, 5%, 200 vdc		Standard
	C204	Capacitor, Type MWR, .039 mfd, 5%, 100 vdc		Standard
	C205	Capacitor, Type MWR, .012 mfd, 5%, 100 vdc		Standard
	C206	Capacitor, Dipped Mica, 470 pf, 5%	DM154715	Arco
	C207	Same as C205		
	C208	Capacitor, polystyrene, .0039 mfd, 5%, 33 vdc		Mial
	C209	Capacitor, Type MWR, .068 mfd, 5%, 100 vdc		Standard
	C210	Same as C204		
	C211	Capacitor, Type MWR, .0075 mfd, 5%, 100 vdc		Standard
	C212, 213	Capacitor, tantilum, 22 mfd, 15 vdc	150D	Spraque
	C214	Same as C209		
	C215	Capacitor, Type MWR, .0022 mfd, 5%, 100 vdc		Standard
	C216 thru C218	Capacitor, ceramic disk, 10 pf, 1000 vdc	10TCC-Q10	Spraque
	C219 thru C221	Capacitor, ceramic disk, 3.3 pf, 1000 vdc	10TCC-VB3	Spraque

TABLE 5-5

HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	C222	Capacitor, paper, .22 mfd, 75 vdc	225P2	Spraque
	C223	Capacitor, ceramic disk, .001 mfd, 1000 vdc	5GA-D10	Spraque
	C224	Same as C222		
	C225	Same as C223		
	C226	Same as C222		
	C227	Same as C223		
	C228	Same as C222		
	C229	Same as C223		
	C230	Same as C222		
	C231	Same as C219		
	C232	Same as C216		
	C233	Capacitor, electolytic, 50 mfd, 25 vdc	TE1209	Spraque
	C234, 235	Same as C222		
	C236 thru C238	Same as C212		
	D201 thru D220	Diode, silicon, IN3064		Fairchild
	D221 thru D224	Diode, silicon, IN2482		Sarkes-Tarzian

TABLE 5-5 HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	IC201 thru IC204	Integrated circuit, dual amplifier	MC1458G or N5558T	Motorola Signetics
	IC205, 206	Integrated circuit, dual amplifier	MC1437L	Motorola
	Q201	Transistor, silicon, 2N3566		Fairchild
	Q202, 203	Transistor, silicon, 2N5138		Fairchild
	Q204	Same as Q202		
	Q205	Same as Q201		
	Q206	Transistor, silicon, 2N3440		RCA
	Q207	Same as Q201		
	Q208	Same as Q206		
	Q209, 210	Same as Q201		
	Q211	Same as Q202		
	Q212	Same as Q201		
	Q213	Same as Q206		
	Q214, 215	Same as Q201		
	Q216	Same as Q202		
	Q217	Same as Q201		
	Q218	Same as Q206		
	Q219, 220	Same as Q201		

TABLE 5-5

HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	Q221	Same as Q202		
	Q222	Same as Q201		
	Q223	Same as Q206		
	Q224	Same as Q201		
	Q225	Same as Q202		
	Q226	Same as Q201		
	Q227	Same as Q206		
	R201	Resistor: fixed, composition, 15K, ± 5%, 2W		Ohmite
	R202	Resistor: fixed, deposited, 14.0K, ± 1%, 1/4W	RN60D	IRC
	R203	Resistor: fixed, deposited, 26.1K, ± 1%, 1/4W	RN60D	IRC
	R205, 206	Resistor: fixed, composition, 10K, ± 5%, 1/4W		Ohmite
	R207	Resistor: fixed, deposited, 41.2K ± 1%, 1/4W	RN60D	IRC
	R208	Resistor: fixed, deposited, 24.3K ± 1%, 1/4W	RN60D	IRC
	R209	Resistor: fixed, deposited, 59.0K, ± 1%, 1/4W	RN60D	IRC
	R210	Resistor: fixed, composition, 82K, ± 5%, 1/4W		Ohmite
	R211, 212	Resistor: fixed, deposited, 19.1K, ± 1%, 1/4W	RN60D	IRC
	R213	Resistor: fixed, deposited, 9.53K, ± 1%, 1/4W	RN60D	IRC
	R214	Resistor: fixed, composition, 24K, ± 5%, 1/4W		Ohmite

TABLE 5-5 HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R215 thru R218	Resistor: fixed, deposited, 10K, ± 1%, 1/4W	RN60D	IRC
	R219	Resistor: fixed, composition, 22 ohm, ± 5%, 1/4W		Ohmite
	R220	Resistor: fixed, deposited, 20K, ± 1%, 1/4W	RN60D	IRC
	R221	Resistor: fixed, composition, 4.7K, ± 5%, 1/4W		Ohmite
	R222	Same as R205		
	R223	Resistor: fixed, composition, 47K, ± 5%, 1/4W		Ohmite
	R224	Resistor: fixed, composition, 100K, ± 5%, 1/4W		Ohmite
	R225	Same as R221		
	R226	Resistor: fixed, composition, 33K, ± 5%, 1/4W		Ohmite
	R227, 228	Resistor: fixed, deposited, 20.5K, ± 1%, 1/4W	RN60D	IRC
	R229	Resistor: fixed, deposited, 12.1K, ± 1%, 1/4W	RN60D	IRC
	R230	Same as R207		
	R231	Resistor: fixed, composition, 22K, ± 5%, 1/4W		Ohmite
	R232	Resistor: fixed, deposited, 31.6K, ± 1%, 1/4W	RN60D	IRC
	R233	Resistor: fixed, deposited, 63.4K, ± 1%, 1/4W	RN60D	IRC
	R234	Resistor: fixed, deposited, 21.5K, ± 1%, 1/4W	RN60D	IRC
	R235	Same as R223		

TABLE 5-5 HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R236	Resistor: fixed, composition, 7.5K, ± 5%, 1/4W		Ohmite
	R237	Resistor: fixed, deposited, 365 ohm, ± 1%, 1/4W	RN60D	IRC
	R238	Resistor: fixed, deposited, 224 ohm, ± 1%, 1/4W	RN60D	IRC
	R239, 240	Resistor: fixed, composition, 1K, ± 5%, 1/4W		Ohmite
	R241, 242	Resistor: fixed, composition, 2.2 Meg, ± 5%, 1/4W		Ohmite
	R243, 244	Same as R231		
	R245	Same as R221		
	R246	Resistor: fixed, composition, 100 ohm, ± 5%, 1/4W		Ohmite
	R247	Same as R224		
	R248, 249	Same as R205		
	R250	Resistor: fixed, composition, 120K, ± 5%, 1/4W		Ohmite
	R251	Resistor: fixed, composition, 200K, ± 5%, 1/4W		Ohmite
	R252	Resistor: fixed, composition, 6.8K, ± 5%, 1/4W		Ohmite
	R253 thru R255	Same as R231		
	R256	Same as R221		
	R257	Same as R239		
	R258	Same as R205		
	R259	Same as R226		

TABLE 5-5 HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R260	Same as R250		
	R261	Same as R251		
	R262	Same as R252		
	R263 thru R265	Same as R231		
	R266	Same as R221		
	R267	Same as R239		
	R268	Same as R205		
	R269	Same as R226		
	R270	Same as R250		
	R271	Same as R251		
	R272	Same as R252		
	R273 thru R275	Same as R231		
	R276	Same as R221		
	R277	Same as R239		
	R278	Same as R205		
	R279	Same as R226		
	R280	Same as R226		

TABLE 5-5

HLI 48-200 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R281	Same as R251		
	R282	Same as R252		
	R283 thru R285	Same as R231		
	R286	Same as R221		
	R287	Same as R239		
	R288	Same as R205		
	R289	Same as R226		
	R290, 291	Same as R221		
	R292, 293	Same as R205		
	R294, 295	Same as R226		
	R296, 297	Same as R223		
	R298	Same as R241		
	R299	Same as R239		
	R2000	Resistor, variable wire wound, 1K, 10%, 1/2W	89PR102	Helipot
	R2001	Same as R231		
	R2002	Same as R221		
	T201	Transformer	124-4C	ADC

TABLE 5-6 HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	C301, 302	Capacitor, ceramic disk, 3.3 pf, 1000 vdc	10TCC-V33	Spraque
	C303, 304	Capacitor, ceramic disk, 10 pf, 1000 vdc	10TCC-Q10	Spraque
	C305	Same as C303		
	C306	Same as C301		
	C307, 308	Capacitor, paper, .22 mfd, 75 vdc	225P22	Spraque
	C309	Capacitor, type MWR, .0033 mfd, 5%, 100 vdc		Standard
	C310, 311	Capacitor, type MWR, .068 mfd, 5%, 100 vdc		Standard
	C312	Capacitor, type MWR, .039 mfd, 5%, 100 vdc		Standard
	C313	Capacitor, type MWR, .0075 mfd, 5%, 100 vdc		Standard
	C314 thru C319	Capacitor, tantilum, 22 mfd, 15 vdc	150D	Spraque
	C320	Same as C312		
	C321	Capacitor, paper, .027 mfd, 100 vdc	225PW	Spraque
	C322	Capacitor, paper, selected value, 100 vdc		Spraque
	C323	Capacitor, paper, .15 mfd, 100 vdc	225PW	Spraque
	C324	Same as C303		
	C325	Same as C301		
	C326	Capacitor, paper, .01 mfd, 100 vdc	225P22	Spraque

TABLE 5-6 HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	C327	Capacitor, type M2WF, 5 mfd, 10%, 200 vdc		Standard
	C328	Capacitor, paper, selected value	225P22	Spraque
	C329	Same as C307		
	C330, C331	Same as C307		
	C332, 333	Same as C303		
	C334, 335	Same as C301		
	C336	Same as C307		
	C337	Capacitor, paper, .22 mfd, 200 vdc	2PS-P22	Spraque
	C338	Capacitor, disk, .01 mfd, 100 vdc	HY-520	Spraque
	C339	Capacitor, Electolytic, 50 mfd, 25 vdc	TE1209	Spraque
	D301 thru D305	Diode, silicon, IN3064		Fairchild
	D306, 307	Diode, silicon, IN706A		Motorola
	D308 thru D314	Same as D301		
	D315, 316	Diode, silicon, IN191		G. E.
	IC301, 302	Integrated circuit, dual amplifier	MC1437L	Motorola
	IC303 thru IC305	Integrated circuit, dual amplifier	MC1458G	Motorola

TABLE 5-6 HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	IC306	Same as IC301		
	L301, 302	Inductor, pot core (adj.), 0.1 mhy	44-008	HLI
	Q301 thru Q307	Transistor, silicon, 2N3566		Fairchild
	Q308, 309	Transistor, silicon, 2N5138		Fairchild
	Q310 thru Q312	Same as Q301		
	R301 thru R304	Resistor: fixed, composition, 10K, ± 5%, 1/4W		Ohmite
	R305	Resistor: fixed, composition, 22K, ± 5%, 1/4W		Ohmite
	R306 thru R311	Resistor: fixed, composition, 100K, ± 5%, 1/4W		Ohmite
	R312 thru R315	Same as R301		
	R316, 317	Same as R305		
	R318, 319	Resistor: fixed, composition, 220K, ± 5%, 1/4W		Ohmite
	R320	Resistor: variable wire wound, 20K, 10%, 1/2W	89PR203	Helipot
	R321	Resistor: fixed, composition, 1K, ± 5%, 1/4W		Ohmite

TABLE 5-6 HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R322	Same as R306		
	R323, 324	Resistor: fixed, deposited, 42.2K, ± 1%, 1/4W	RN60D	IRC
	R325	Resistor: fixed, deposited, 21.0K, ± 1%, 1/4W	RN60D	IRC
	R326	Resistor: fixed, composition, 47K, ± 5%, 1/4W		Ohmite
	R327	Same as R318		
	R328	Same as R301		
	R329	Resistor: fixed, composition, 5.6K, ± 5%, 1/4W		Ohmite
	R330, 331	Resistor: fixed, deposited, 20.5K, ± 1%, 1/4W	RN60D	IRC
	R332	Resistor: fixed, deposited, 12.1K, ± 1%, 1/4W	RN60D	IRC
	R333	Resistor: fixed, deposited, 41.2K, ± 1%, 1/4W	RN60D	IRC
	R334 thru R336	Same as R305		
	R337, 338	Resistor: fixed, composition, 33K, ± 5%, 1/4W		Ohmite
	R339	Same as R301		
	R340	Resistor: fixed, composition, 2.2 Meg, ± 5%, 1/4W		Ohmite
	R341, 342	Same as R305		
	R343 thru R345	Same as R320		
	R346	Resistor: fixed, composition, 91K, ± 5%, 1/4W		Ohmite

TABLE 5-6

HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R347, 348	Same as R306		
	R349	Resistor: fixed, composition, 68K, ± 5%, 1/4W		Ohmite
	R350	Same as R321		
	R351	Resistor: fixed, composition, 1.5K, ± 5%, 1/4W		Ohmite
	R352, 353	Same as R301		
	R354	Same as R306		
	R355	Resistor: fixed, composition, 2.2K, ± 5%, 1/4W		Ohmite
	R356	Resistor: fixed, composition, 220 ohm, ± 5%, 1/4W		Ohmite
	R357	Same as R337		
	R358, 359	Same as R355		
	R360	Resistor: fixed, composition, 1.2K, ± 5%, 1/4W		Ohmite
	R361	Resistor: fixed, composition, 4.7K, ± 5%, 1/4W		Ohmite
	R362, 363	Same as R306		
	R364	Same as R355		
	R365	Same as R356		
	R366 thru R369	Resistor: fixed, deposited, 10.0K, ± 1%, 1/4W	RN60D	IRC
	R370	Resistor: fixed, deposited, 20.0K, ± 1%, 1/4W	RN60D	IRC

TABLE 5-6 HLI 48-300 BOARD PARTS LIST

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R371	Same as R305		
	R372, 373	Same as R361		
	R374	Same as R321		
	R375	Same as R355		
	R376	Same as R340		
	R377, 378	Same as R305		
	R379	Resistor: fixed, composition, 100 ohm, ± 5%, 1/4W		Ohmite
	R380, 381	Same as R301		
	R382	Same as R306		
	R383	Resistor: variable wire wound, 1K, 10%, 1/2W	89PR102	Helipot
	R384	Same as R351		
	R385, 386	Same as R366		
	R387	Resistor: fixed, composition, 5K, ± 5%, 1/4W		Ohmite
	R388	Same as R306		
	R389	Same as R361		
	T301	Transformer, Audio	DCM-9-PC	Microtran

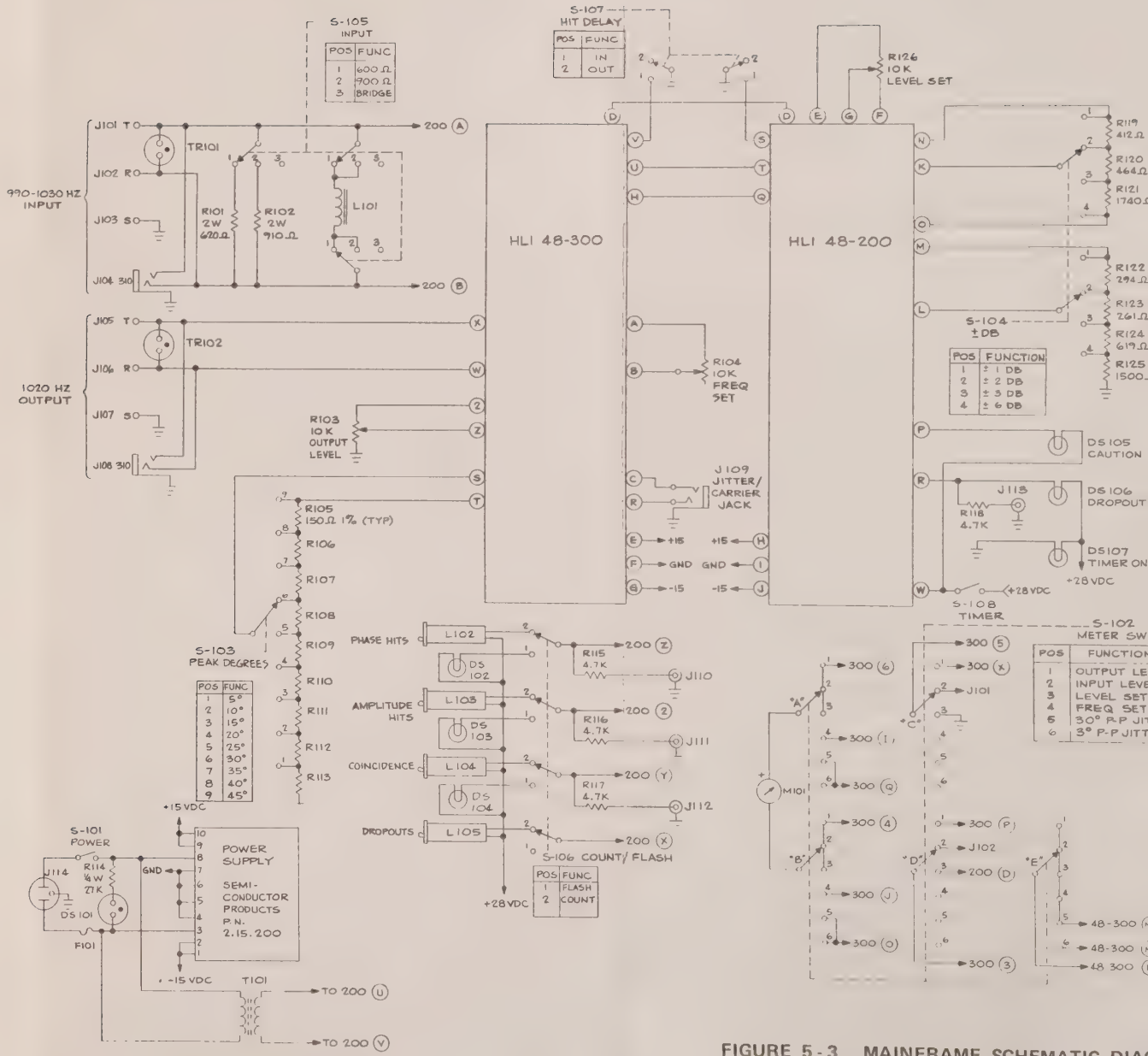


FIGURE 5-3 MAINFRAME SCHEMATIC DIAG

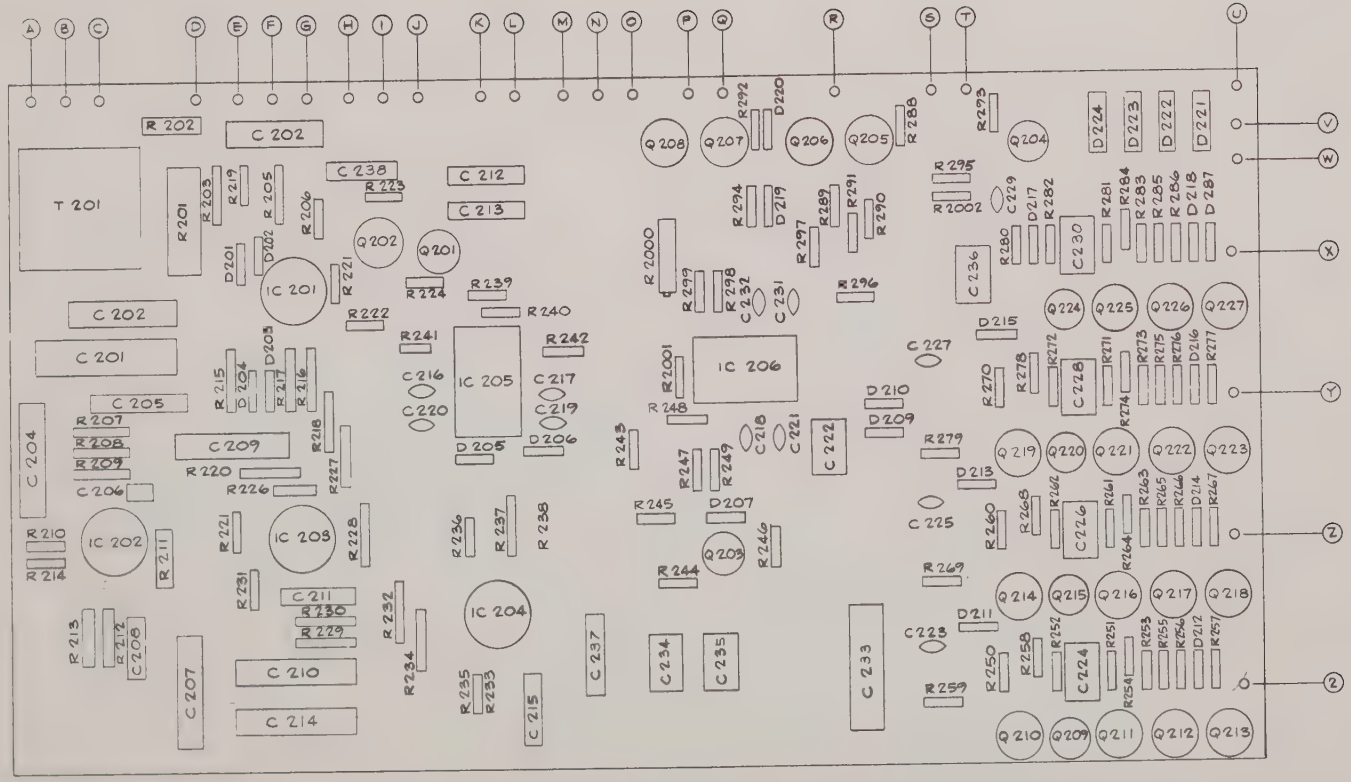


FIGURE 5–4 HLI 48–200 P.C. BOARD COMPONENT LAYOUT

NOTES
1. TYPE 1437 IC'S HAVE -15V DC ON PIN 7 AND +15V DC ON PIN 14
2. TYPE 1458 IC'S HAVE -15V DC ON PIN 4 AND +15V DC ON PIN 8
3. ALL UNMARKED CAPACITY VALUES IN MFD
4. ALL UNMARKED DIODES ARE TYPE IN3064
* SELECTED VALUE

PIN DIAGRAMS - BOTTOM VIEW

IC'S

ALL TRANSISTORS

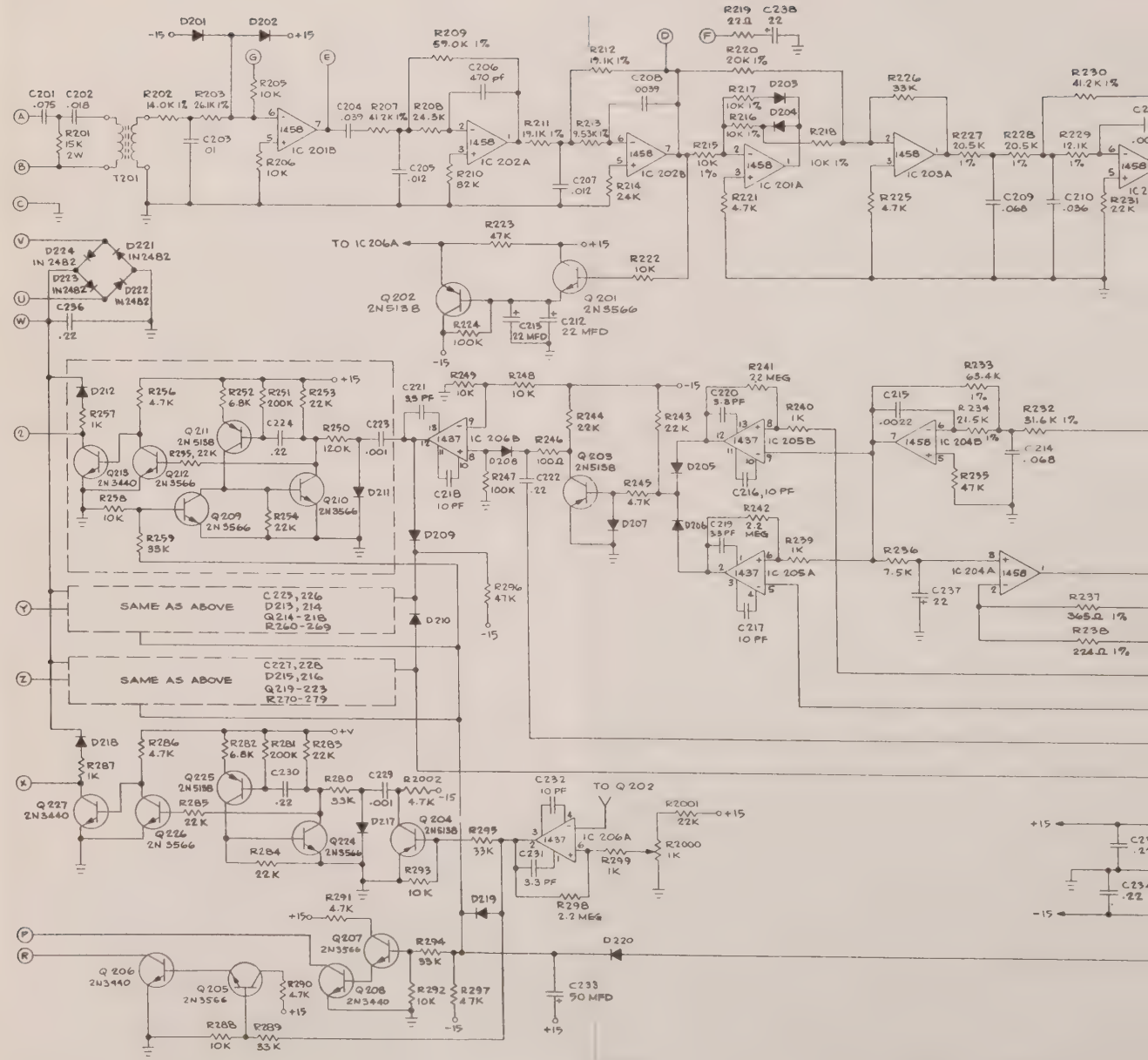


FIGURE 5-5 HLI 48-200 P.C. BOARD SCHEMATIC DIAGR

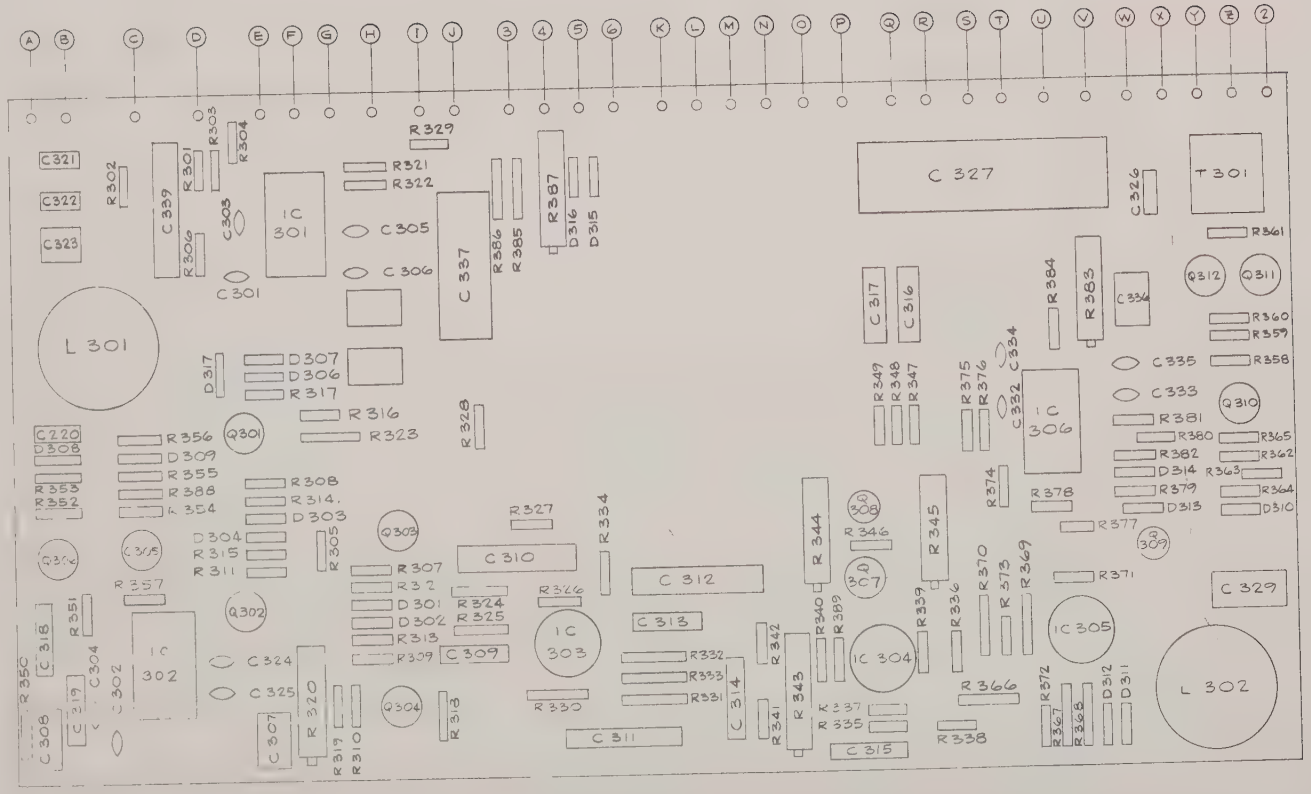


FIGURE 5–6 HLI 48–300 P.C. BOARD COMPONENT LAYOUT

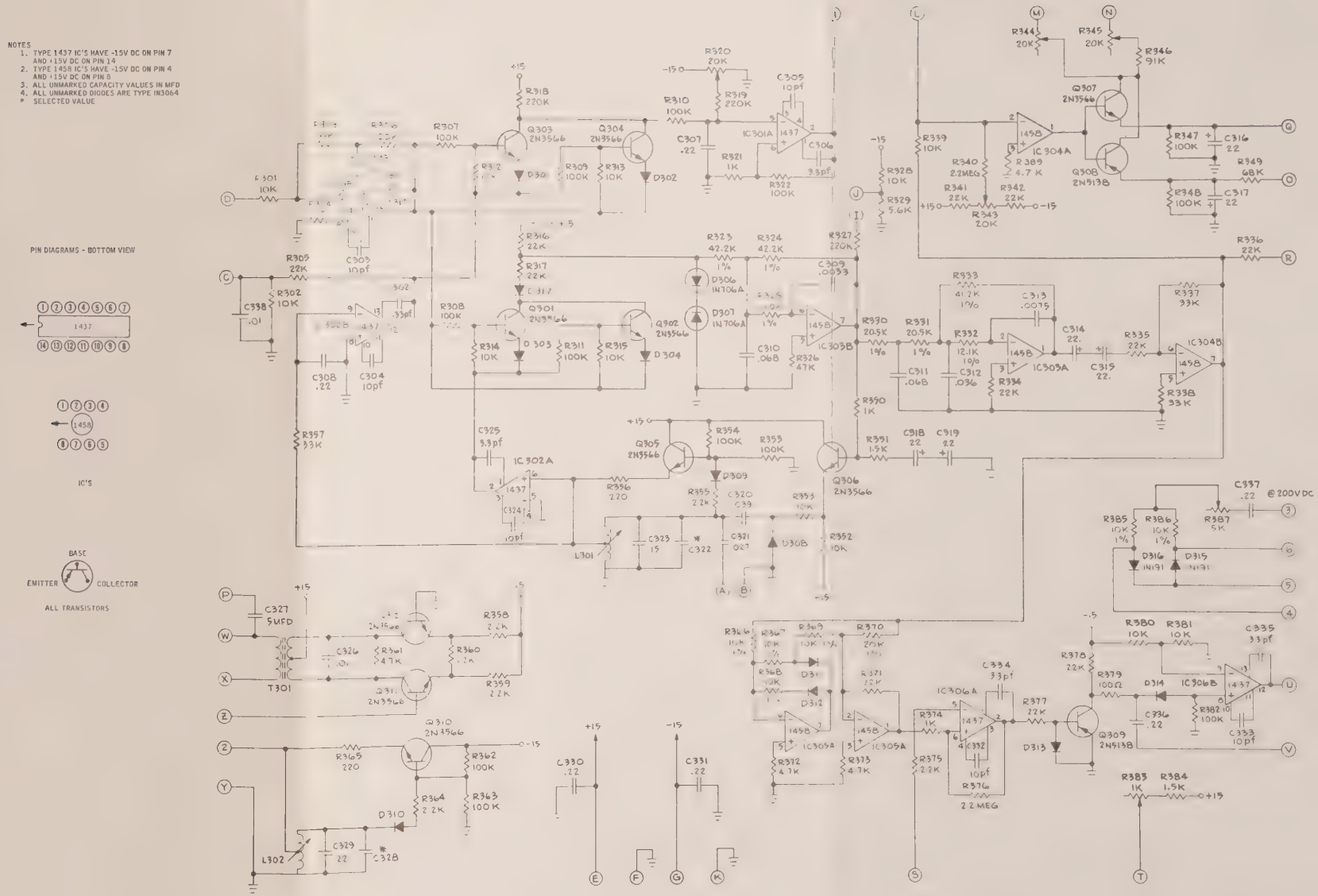


FIGURE 5-7 HLI 48-300 P.C. BOARD SCHEMATIC DIAGRAM

WARRANTY

All Hekimian Laboratory, Inc. products are warranteed against defects in materials and workmanship for a period of one year from date of delivery. HLI will repair or replace at no cost, products which prove to be defective during the warranty period. Upon authorization by HLI, the equipment may be returned to the factory prepaid for repair. Upon completion of repair, the equipment will be returned at HLI expense. If, upon examination of the defective item, it is evident that failure was not due to defective workmanship or material, HLI will bill the purchaser for the cost of replacement or repair, including transportation charges. No other warranty is expressed or implied and HLI is not liable for consequential damages.

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